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THE

MINERALS AND GEOLOGY

OF

CENTRAL CANADA,

comprising the

PROVINCES OF ONTARIO AND QUEBEC.

WITH

explanatory and technical observations on minerals, rocks and fossils, generally. A HAND-BOOK FOR PRACTICAL USE.

> By E. J. OHAPMAN, Ph. D., LL. D.

Second Edition Revised and enlarged.

TORONTO:

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OF THE

MINERALS AND GEOLOGY OF CANADA.

INTRODUCTORY NOTICE.

The aim of the present work is to impart, in a simple and condensed form, a practical knowledge of Canadian minerals and rock formations, including, with the latter, the various fossilized bodies which so many of these rocks contain, and by which their respective ages and positions are principally established. As the work is intended strictly for the student and general reader, it seeks to convey this knowledge without exacting the mastery of minute scientific details; although, if taken up by persons unacquainted with geology, a work of this kind, however elementary its treatment, will necessarily require to be studied before it can be read. Geology, in the proper acceptation of the term, comprises the History of the Earth, as distinct from records of human action and progress : a history revealed to us by the study of the rock masses which lie around and beneath us; and by a comparison of the results of ancient phenomena, as exhibited in these rocks, with the forces and agencies still at work in modifying the surface of the globe. As Geology is thus essentially based on the study of rocks and their contents, and as rocks are not only made up of a certain number of simple minerals, but contain also many of these latter in veins and other more or less accidental forms of occurrence, it is advisable at the outset to obtain a certain knowledge of the distinctive characters of minerals, and of the application of these characters to the determination of mineral bodies generally. This achieved, we may proceed to the study of the more extended mineral masses, or rocks proper : viewing these as regards their classification, structural characters, composition, modes of formation, and other related points of inquiry. The study of Organic

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Remains comes next in order—these bodies, the representatives of departed forms of life, occurring in great numbers in many strata. They serve not only for the practical identification of the rock groups in which they are inclosed—and thus enable us to determine, for instance, whether a given bed lie above or below the great coal formation or other geological horizon—but they make known also many interesting facts with regard to the climatic relations of the l'ast, and explain in many ways the general plan and great progressive march of Creation. Finally, with the information obtained from these preliminary sections, the reader may turn with profit to the study of our local geology.

In accordance with these views, the subject-matter of the present treatise is discussed under the following subdivisions :

I. The Distinctive Characters of Minerals.

- II. The Minerals of Central Canada, or Provinces of Ontario and Quebec.
- III. Rocks and Rock-producing Agencies.

IV. Organic Remains.

V. The Geology of Canada proper—comprising the Subdivisions, Characteristic Fossils, Economic Materials, and Topographical Distribution, of the various Geological Formations occurring within the Provinces of Outario and Quebee.

PART I.

THE DISTINCTIVE CHARACTERS OF MINERALS.

Preliminary Remarks :- The various bodies which occur in Nature are of two general kinds-Organic and Inorganic, respectively. The former constitute Vegetables and Animals, and all bodies of vegetable or animal origin. In the living state, they possess certain structural parts or organs by which they assimilate or take into their substance external matter, and thus increase in bulk or maintain vitality. Inorganic bodies, on the other hand, are entirely destitute of functional organs of this nature. They comprise all metals, stones and rocks; air, water, and other products of chemical, electrical, and mechanical forces, acting independently of life.

4

Mineral or inorganic bodies are in themselves, also, of two general kinds. Some possess a definite composition and definite physical characters. Others are mixed bodies or compounds of more or less variable character. The former constitute simple minerals or minerals proper; the latter form rocks or rock-matters. In Parts I and II of this Treatise, minerals proper are alone considered. Rocks and rock-producing agencies, come under review in Part III and in succeeding portions of the work.

Minerals are distinguished from one another by certain characters or properties which they possess : such as form, degree of hardness, relative fusibility, &c.

Mineral characters are of two principal kinds : physical or external, and chemical, respectively. Physical characters comprise the various properties exhibited under ordinary conditions by mineral bodies : colour, form, &c., are examples. Chemical characters, on the other hand, comprise the properties developed in minerals by the application of heat, or the action of acids or other re-agents, by which, in general, a certain amount of chemical decomposition is effected.

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Chemical.

A. PHYSICAL CHARACTERS OR PROPERTIES.

The physical properties of minerals are somewhat numerous; but many, although of the highest interest in indicating the existence of natural laws, and in their relations to physical science generally, are not readily available as a means of mineral discrimination. These, consequently, will be omitted from consideration in the following pages; and the other characters will be discussed only in so far as they admit of direct application to the end in view—namely, the practical discrimination of minerals one from another.*

The following are the characters in question :

- -1. Aspect or Lustre.
- 2. Colour.
- 3. Streak.

·4. Form.

-5. Structure.

. 6. Hardness.

- >7. Specific gravity.
- 8. Relative Malleability.
- 9. Magnetism.
- 10. Taste.

Aspect or Lustre.—In reference to this character we have to consider first, the kind, and, secondly, the degree or intensity of lustre, as possessed by the mineral under examination. The kind of lustre may be either metallic, as that of a piece of copper, silver, &c.; or <u>submetallic</u>, as that of most kinds of anthracite coal; or <u>non-metallic</u>, as that of stones in general. Of the non-metallic lustre there are several varieties, as, more especially: the <u>adamantine</u> lustre or that of the

FOURTH GROUP :- Sensationary Characters :- 1, Weight (Specific Gravity). 2, Feel, 3, Taste. 4, Odour. 5. Sound.

FIFTH GROUP :- Physical Characters, proper :--1, Magnetism. 2, Electricity. 3, Phosphores cence.

SIXTH GROUP:-Epigenic Characters:-1, Taruish. 2, Ordinary Disintegration and Decomposition. 3, Efflorescence. 4, Deliquescence.

^{*} Viewed collectively, the Physical Characters of Minerals may be arranged for the purposes of study, under six groups, as follows :

FIRST GROUP :- Morphological Characters :- 1, Form. 2, Surface-condition. 3, Structure. 4, Cleavage. 5, Fracture.

SECOND GROUP:-Optical Characters:-1, Aspect, or Kind of Lustre. 2, Degree of Lustre. 3, Colour. 4, Streak. 5, Degree of Transparency. 6, Refraction. 7, Polarization.

THIND GROUP:--Cohesion Characters:--1, Hardness. 2, Tenacity. 3, Malleability. 4, Expansiblity.

PHYSICAL CHARACTERS OF MINERALS.

diamond, carbonate of lead, &c.; the vitreous or glassy lustre-example : rock crystal; the resinous lustre-ex.: native sulphur; the pearly lustre-ex.: tale; the silky lustre (usually accompanying a fibrous structure)-ex.; fibrous gypsum; the stony aspect; the earthy aspect, &c. These terms sufficiently explain themselves. Occasionally, two kinds of non-metallic lustre are simultaneously present-either blended, as seen in obsidian, which exhibits a "resino-vitreous" aspect; or distinet as regards different crystal faces or external and internal surfaces. Many of the so-called Zeolites, for example, present a pearly lustre ou the surfaces produced by cleavage (see beyond), whilst the external lustre is vitreous. In Apophyllite, the basal or terminal crystal-plane is pearly, the others vitreous. Mieas, and some few other minerals, present a pseudo-metallic lustre. This may be distinguished from the metallic lustre properly so-called, by being accompanied by a degree of translucency, or by the powder of the mineral being white or faintlycoloured : minerals of a true metallie aspect being always opaque, whilst their powder is either black or distinctly coloured. Very few minerals exhibit (in their different varieties) more than one general kind of lust : metallie or non-metallie. Thus, galena, the common ore of lead, copper pyrites, &c., always present a metallic lustre; whilst, on the other hand, quartz, feldspar, cale-spar, gypsum, &c., are never found otherwise than with a non-metallic aspect. Hence, by means of this easily-recognized character, we may divide all minerals into two broad groups; and thus, if we pick up a specimen, and wish to ascertain its name, we need only look for it amongst the minerals of that group with which it agrees in lustre. The first step towards the determination of the substance will in this way be effected.

The degree of lustre may be either splendent, shining, glistening, glimmering, or dull; but the character is one of comparatively little importance.

(1)

Colour.—When combined with a metallic aspect, colour becomes a definite character, and is thus of much value in the determination of minerals. As regards a substance of metallic aspect, for example, specimens brought from different localities, or occurring under different conditions, rarely vary in colour beyond a slight difference of depth or shade. Thus, galena, the common ore of lead, is always lead-gray; copper pyrites, always brass-yellow; native gold, always gold-yellow; and so forth. When accompanied, however, by a vitreous or other non-

metallic lustre, colour becomes a character of no practical value, as a mineral of non-metallic aspect may present, in its different varieties, every variety of colour. Thus, we have colourless quartz, amethystine or violet quartz, red quartz, yellow quartz, &c. Also, feldspars, fluorspars, and other minerals of variable colour : just as in the Vegetable Kingdom, we have red, white and yellow roses, and dahlias, &c., of almost every hue. The more common shades of metallic colour are as follows :

White	Silver-white ex. Native silver. Tin-white ex. Pure tin; cobalt ore.
Grey	Lead-grey ex. Galena. Steel-grey ex. Specular iron ore.
Black	.Iron-black (usually with sub-metallic lustre) ex. Magnetic iron ore.
Yellow	Go ¹ d-yellow ex. Native gold. Brass-yellow ex. Copper pyrites. Bronze-yellow (a brownish-yellow) ex. Magnetic pyrites.
Red	.Copper-red ex. Native copper.

These metallic colours are often more or less obscured by a black, brownish, purple, or iridescent surface-tarnish. In noting the colour of a mineral, this must be constantly borne in mind, and if possible, a newly-fractured surface should be observed. The non-metallic colours comprise, white, grey, black, blue, green, red, yellow, and brown, with their various shades and intermixtures : as orange-yellow, straw-yellow, reddish-brown, greenish-black, &c. In minerals of a non-metallic aspect, the colour is sometimes uniform; and at other times, two or more colours are present together, in spots, bands, &c., as in the varieties of quartz, called agate, blood-stone, jasper, and so forth. In most varieties of Labradorite, or Labrador Feldspar, a beautiful play or change of colour is observable in certain directions. The finer varieties of Opal also exhibit a beautiful and well-known iridescence.

Streak.—Under this technical term is comprised the appearance or colour of the scratch, produced by drawing or "streaking" a mineral across a file or piece of unglazed porcelain. The character is a valuable one on account of its uniformity: as, no matter how varied the colour of a mineral may be in different specimens, the streak will remain of one and the same colour throughout. Thus, blue, green, yellow, red, violet, and other specimens of fluor spar, quartz, &c., exhibit equally a white or "uncoloured" streak. The streak is sometimes "unchanged," or of the same tint as the external colour of the mineral; but far more frequently it presents a different colour. Thus, Cinnabar, the ore of

PHYSICAL CHARACTERS OF MINERALS.

mercury, has a red colour and red streak; Realgar, red sulphide of arsenic, has a red colour and orange-yellow streak; Copper Pyrites, a brass-yellow colour, and greenish-black streak; and so forth. In certain malleable and sectile minerals, the scratched surface presents an increase of lustre. The streak is then said to be "shining." Finally, it should be remarked, that in trying the streak of very hard minerals, we must crush a small fragment to powder, in place of using the file; because otherwise, a greyish-black streak, arising from the abrasion of the file, might very possibly be obtained, and so conduce to error.

Form.-The forms assumed by natural bodies are of two general kinds: (1) Accidental or Irregular, depending rather on external conditions than on the actual nature of the body; and (2), Essential or Accidental forms occur only as monstrosities in Organic Regular. Nature. Amongst minerals, on the other hand, they are of frequent occurrence; but the Mineral Kingdom possesses also its definite or essential forms. These, whether transparent or opaque, are termed crystals. This term was first applied to transparent vitreous specimens of quartz or rock-crystal, from the resemblance of these to ice; but as it is subsequently found that many opaque specimens of quartz present exactly similar forms, and that opaque as well as transparent forms of other minerals occur, the term, in scientific language, gradually lost its original signification, and came to be applied to all the geometrical or regular forms of minerals and other inorganic bodies, whether transparent, translucent, or opaque. As already remarked, minerals of a metallic lustre are always opaque; and many of these, galena, ironpyrites, arsenical-pyrites, &c., occur frequently in very regular and symmetrical crystals.

As regards the regular or essential forms of Nature, two distinct and in a measure antagonistic form-producing powers—*Vitality* and *Crystallization*—thus appear to exist. Forms which arise from a development of the vital force, exhibit rounded and confluent outlines; whilst those produced by crystallization are made up of plain surfaces, meeting, in sharp edges, under definite and constant angles.* (!rystals originate in]

⁴ This law is affected within slight limits by isomorphous replacements, and also by changes of temperature. The law itself appears to have been discovered by Nicolaus Steno (a naturalized Florentine) as early as 1669, but its true importance was not appreciated until the re-announcement, or rather re-discovery of the law in 1772, by the French crystallographer, Romé de l'Isle. Many of the contemporaries of the latter—amongst others the celebrated Buffon—attempted to deny its existence; but being susceptible of practical proof, its truth was soon established.

almost all cases in which matter passes from a gaseous or liquid into a solid state; but if the process take place too quickly, or the matter solidify without free space for expansion, crystalline masses, in place of regular crystals, will result. If a small fragment of arsenical pyrites, or native arsenic, be heated at one end of an open and narrow glass tube, the arsenic, in volatilizing, will combine with oxygen from the atmospher., and form arsenious acid, which will be deposited at the other end of the tube, in the form of minute octahedrons (Fig. 3, below). In like manner, if a few particles of common salt be dissolved in a small quantity of water, and a drop of the solution be evaporated gently (or be left to evaporate spontaneously) on a piece of glass, numerous little cubes and hopper-shaped cubical aggregations will result. Boiling water, again, saturated with common alum, will deposit octahedral crystals on cooling; the cooled water not being able to retain in solution the full amount of alum dissolved by the hot water. Finally, it may be observed that sulphur, bismuth, antimony, and many other bodies, crystallize by slow cooling from the molten state. Although, as explained above, crystals usually originate when matter passes slowly from the gaseous or liquid condition into the solid erystallization and solidification are not actually identical. Various substances, such as silica in certain conditions, its hydrate (constituting the different opals), gums, many resins, &c., appear to resist altogether the action of crystallization.

The crystal forms and combinations met with in Nature, exclusive of those produced by the chemist in his laboratory, are exceedingly numerous, many thousands being known to exist. By the help of certain laws, however, and, more especially, by the aid of one, termed "the Law of Symmetry," we are enabled to resolve these multitudinous combinations into six groups or systems. The forms of the same group combine together, and may be deduced mathematically from each other; whilst those of distinct groups are unrelated. Thus, although the cube, the rhombic dodecahedron, and the regular octahedron (Figs. 1, 2 & 3) appear at first sight to be unconnected forms, yet by the Law of Symmetry their co-relations may be readily shown. This law, for instance, exacts one of three things, of which the most important is to this effect, viz., that if an edge or angle of a crystal be modified in any way, all the similar edges or angles in the crystal must be modified in a similar manner. Now the cube has twelve similar edges and eight similar angles. Consequently, if one edge or one angle be truncated,

PHYSICAL CHARACTERS OF MINERALS.

or, to use a term more in conformity with the actual operations of Nature, if one of these be suppressed during the formation of the crystal, the other edges (or angles) must be suppressed also; and if the new planes, which thus arise, be extended until they meet, the rhombie dodecahedron on the one hand, and the regular octahedron on the other, will result.* These forms, moreover, as well as their intermediate oscillations, frequently occur in the same substance : red oxide of copper may be eited as an example. But between the cube, a square prism, a regular hexagonal prism, and a rhombic prism, no relations of this kind exist. Neither are these solids related physically: their optical, thermal, and other physical relations are equally distinct. By considerations of this sort, therefore, we are able to establish six (or really seven) distinct Crystal Systems. These (named chiefly in accordance with the relations of their axes, or certain right lines assumed to pass through the centre of each crystal, and terminate in opposite planes, edges, or angles) are enumerated in the annexed tabular view:

Crystal-axes of one length. Refraction, single	The Monometric System (including the cube, rhombic dodecahedron, octahedron, &c., with their vari- ous combinations.)		
Crys. Waxes of two lengths. Refraction, double, with one neutral line or optical axis	The Dinetric Sp and pyramid The Hexagonal prisms and p their combine	eston (including square-based prisms s with their various combinations) System (including regular hexagonal vramids, rhombohedrons, &c., with ations.)	
Crystal-axes of three lengths Refraction, double, with	Axes at right- angles.	The Trimetric System (including right rectangular prisms and pyramids, rhombic prisms and pyramids, and combinations of these.	
two neutral lines or opti- cal axes	One axis ob- lique.	The Monoclinic System (including oblique rectangular and rhombic combinations,	
	All the axes oblique.	The Triclinic System (including doubly-oblique combinations.)	

The study of these Crystal groups, and that of crystal forms and combinations generally, constitutes the science of Crystallography. To

^{*} The Law of Symmetry, in its exact acceptation, may be thus expressed :

^(1.) If an edge or angle of a crystal be modified, all the similar edges or angles must exhibit) a similar modification.

Or (2.) One-half or one-muth of the corresponding angles or edges, in alternate positions, must be equally modified. Example.—Cube and Tetrahedron (Boraeite; Arseniate of Iron.)

Or (3), All the similar edges or angles must be modified by one-half or one-mit the normal or regular number of planes. Example.—Cube and Pentagonal Dodecahedron (Iron Pyrites, Cobaltine).

Conditions 2 and 3 produce bemihedrons or part-forms.

enter into the details of this science would extend our present discussion much beyond its proposed limits and object, the simple determination of commonly occurring minerals; but it will be advisable for the student to impress upon his memory the names of the groups in question, with the general aspect of their more common forms and combinations, as given in the following enumeration.*

The Monometric or Regular System.—This group includes the cube (Fig. 1), the <u>rhombic dodecahedron</u> (Fig. 2), the <u>regular octahedron</u> (Fig. 3), <u>trapezohedrons or leucitoids</u> (Fig. 4), <u>pentagonal dodecahe</u> drons (Fig. 5), &c. Fig. 6 is a combination of the cube and octahedron;



No. 7, a combination of the cube and pentagonal dodecahedron. Native gold, silver, copper, iron pyrites, galena, zine blende, grey copper ore, red copper ore, <u>magnetic iron ore</u>, spinel, garnet, <u>fluor spar, rock</u> <u>salt</u>, and numerons other minerals, <u>crystallize in this system</u>.

⁴ The reader, who may wish to take up the study of Crystallography in a more extended manner, may attend the author's special courses of lectures which include that subject. In these, the use of crystallographic instruments is shewn, and the lectures are illustrated by muncrous wood and porcelain models, drawings, and natural crystals. The following is extracted from the syllabus of the advanced course on Mineralogy :

CHVSTALLOGRAPHY.—PART I. General Principies of Crystallography :—Crystals, how defined. Formation of Crystals. Elements of Crystals: planes, edges, angles, diagonals, axes. Forms and Combinations. Replacing planes. General Nomenclature of Forms and Simple Crystals. Law of Constant Angles. Measurement of Angles. Laws of Symmetry : Holohedral and Hemilhedral Forms. Classification of Crystals. Dimorphism. Isomorphism. Compound Crystals. Distortions. Pseudomorphs. PART II. The Systems of Crystallization :—The Monometric System. Dimetric System. Hexagonal System. Trimetric System. Monoclinic System. Tricclinic System. Determinative Crystallography : Method of ascertaining the System of a given Crystal, PART II. Optical and other physical relations of Crystallography. See also the Author's Pamphlet on the Application of Trigonometry to Crystallographic calculations.

PHYSICAL CHARACTERS OF MINERALS.

The Dimetric or Tetragonal System.—This includes, principally, square-based prisms and pyramids (or octahedrons), and their combinations. Figures 8 to 9 are examples of Dimetric crystals. Amongst

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minerals, Copper Pyrites, Tin-stone, Rutile, Anatase, Zircon, Idoerase, &c., may be eited as belonging to the group.

The Hexagonal System.—Regular six-sided prisms (Fig. 10), and pyramids (Fig. 11), combinations of these (Fig. 12), three sided prisms, rhombohedrons (Figs. 13 and 14), and scalenohedrons (Fig. 15); are included under this system. Graphite, Red Silver Ores, Ciunabar, Specular Iron Ore, Corundum, Quartz, Beryl, Tourmaline, Apatite or Phosphate of Lime, Phosphate and Arseniate of Lead, Calcareous Spar,



Dolomite, and Carbonate of Iron, are some of the principle minerals which belong to it.

The Trimetric or Rhombic System.—This system includes rightrhombic prisms, rectangular prisms, rhombic octahedrons, &c., and their



other erystals of this system. Prismatic Iron-pyrites, Mispickel or Arsenical pyrites, Native Sulphur, Topaz, Staurolite, Arragonite, Heavy spar, Celestine, and Epsom sult, are some of the principal minerals which belong to the Trimetrie group.

The Monoclinic or Oblique Rhombic System.—Rhombic prises and pyramids, and rectangular prisms and pyramids, with oblique or ping base, belong to this system. Figs. 22 to 24 are Monoclinic combinations. Characteristic minerals comprise: Augite, Hornblende, Epidote, Sphene, Orthoclase or Potash Feldspar, Gypsum, and Iron Vitriol or Sulphate of Iron.



The Triclinic or Doubly Oblique System.—The forms of this system are oblique in two directions. The crystals in general are more or less flat and unsymmetrical in appearance. No two planes meet at right angles; and there are never more than two similar planes present in any cr ' belonging to the group. Axinite, Albite or Soda-Feldspar, and _ ______ ate of Copper, Fig. 25, are examples of Triclinic minerals.

The Irregular Forms assumed by minerals are of very subordinate importance. The following are some of the more common :-- Globular

PHYSICAL CHARACTERS OF MINERALS.

or nodular, ex. quartz, iron pyrites; reniform or kidney-shaped, ex. quartz, &c.; botryoidal or mammillated: a form made up of a series of rounded elevations and depressions, or otherwise exhibiting a surface of this character, ex. red and brown iron ore, calcedony, &c.; stalactitic, ex. calc. spar, &c.; coralliform, resembling certain branching corals, ex. arragonite; dendritic or arborescent, a branching form, often made up of small aggregated crystals, ex. native silver, native copper, &c.; filiform or wire-like, ex. native silver.. When a mineral presents a perfectly indefinite shape, it is said to be massive. Other terms used in connection with the irregular forms of minerals, such as incrusting, disseminated, &c., explain themselves. The term amorphous is applied to obsidian, opal, and other minerals, in which crystalline structure and cleavage planes are altogether wanting.

Structure,-In the majority of minerals, a certain kind of structure, or, in other words, the shape as well as the mode of aggregation of the smaller masses of which they are composed, is always observable. Structure in minerals may be either lamellar, laminar or foliated, prismatic, fibrous, granular or compact. When the mineral, as in most varieties of calc-spar, heavy-spar, feldspar, and gypsum, for example, is made up of broad, tabular masses producing a more or less stratified appearance, the structure is said to be lamellar. When the tabular masses (whether straight, wavy, or curved,) become extremely thin or leafy, as in mica more especially, the structure is said to be laminar, or foliated, or sometimes mieaceous. The scaly structure is a variety of this, in which the laminæ are of small size. When the component masses are much longer than broad or deep, as in many specimens of tourmaline, beryl, calc-spar, &c., the structure is said to be prismatic or columnar. When the prismatic concretions become very narrow, the fibrous structure originates. Fibrous minerals may have either: a straight or parallel-fibrous structure, as in many specimens of gypsum, cale-spar, &c.; an irregularly-fibrous structure, as in many specimens of augite and hornblende; or a radiated-fibrous structure, as in the radiated varieties of iron pyrites, natrolite, wavellite, and many other minerals, - the fibres radiating from one or more central points. Minerals made up of small grains or granular masses are said to have a granular structure; ex. granular or saccharoidal limestone, granular gypsum, &c. Finally, when the component particles are not apparent, the mineral is said to have a compact structure, as in the native malleable metals, obsidian, and most varieties of quartz. Hard and vitreous minerals of a compact structure (cx. obsidian), generally show when broken, a <u>conchoidal fracture</u>, or a series of circular markings resembling the lines of growth on the external surface of a bivalve shell.

Almost all minerals, especially those of a lamellar structure, break or separate more readily in certain directions than in others. This peculiarity is called <u>cleavage</u>. When cleavage takes place in more than one direction, the resulting fragments have often a perfectly regular or definite form. Thus the purer specimens of cale-spar, no matter what their external form, break very readily into rhombohedrons, which measure 105°5° over their obtuse edges. Galena, the common ore of lead, yields rectangular or cubical cleavage forms; whilst the cubes of fluor-spar break off most readily at the corners or angles, and yield regular octahedrons (fig. 3).

Hardness.—The hardness of a mineral is its relative power of resisting abrasion, not that of resisting blows; many of the hardest minerals being exceedingly brittle. Practically, the character is of great importance. By its aid, gypsum may be distinguished in a moment from calcspar or ordinary limestone, cale-spar from feldspar, and copper pyrites from iron pyrites, not to mention other examples.* The degree of hardness in minerals is conventionally assumed to vary from 1 to 10 (1 being the lowest), as in the following scale, devised by a German mineralogist, Miss, and now generally adopted :

1. Foliated TALC.

2. ROCK SALT, a transparent cleavable variety.

3. CALCAREOUS SPAR, a transparent variety. (Calcute)

4. FLUOR SPAR.

5. APATITE.

6. FELDSPAR.

7. ROCK CRYSTAL. & Luce 4

8. TOPAZ.

9. CORUNDUM.

10. THE DIAMOND.

^b Gypsum may be seratched by the finger-nail; Cale-spar and copper pyrites are scratched easily by a knife; whilst feldspar and iron pyrites are hard enough to scratch window-glass. Some years ago, as mentioned by Sir William Logan, a farmer in the Ottawa district was put for much expense and aunoyance by mistaking feldspar for crystalline limestone, and attempting to burn it into lime. On a late visit to the township of Marmora, we found, near a descried kiln, a large heap of quartz fragments, on which a similar attempt had evidently been made.

PHYSICAL CHARACTERS OF MINERALS.

19

In order to ascertain the hardness of a mineral by means of this scale, we attempt to seratch the substance, under examination, by the different specimens belonging to the scale; beginning with the hardest, in order not to expose the specimens to unnecessary wear. Or, proceeding in another manner, we take a fine file, and compare the hardness of the mineral with that of the individual members of the scale, by drawing the file quickly across them. The comparative hardness is estimated by the resistance offered to the file; by the noise occasioned by the file in passing across the specimens; and by the amount of powder so produced. The degree of hardness of the mineral is then said to be equal to that of the member of the scale with which it agrees the nearest. Thus, if the mineral agree in hardness with fluor-spar, we say, in its description, H (or hardness)= 4. If, on the other hand, it be somewhat softer than fluor-spar, but harder than calcareous spar, we say, H = 3.5. Finally, if, as frequently happens, the hardness of a mineral vary slightly in different specimens, the limits of the hardness are always stated. Thus, if in some specimens, a mineral agree in hardness with calc-spar, and in others with fluor-spar, we say, H = 3to 4; or, more commonly, II = 3 - 4. If the hardness be very rigorously tested, it will frequently be found to differ slightly on different faces of a crystalized specimen, or on the broad faces and the edges of the luminæ of foliated specimens; but this, so far as regards the simple determination of minerals, is practically of little moment.

As the minerals of which the scale of Möhs consists, are not in all places obtainable, or always at hand when required, the author of this work devised some years ago a scale of hardness, so contrived as to agree closely enough for practical purposes with that of Möhs, whilst exacting for its application only such objects as are always to be met with. The following is the scale in question : its use explains itself.*

Chapman's Convenient Scale of Hardness, to correspond with that of Möhs.

- 1. Yields easily to the nail.
- 2. Does not yield to the nail. Does not seratch a copper coin.
- 3. Scratches a copper coin, but is also scratched by one, being of about the same degree of hardness.

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^{*} This scale was first published in 1843. The compiler of the article "Mineralogy" in the last edition of the *Encyclopedia Britannica* has copied it (to avoid acknowledgement) under a somewhat clumsy disguise.

- 4. Not scratched by a copper coin. Does not scratch glass (ordinary window-glass).
- 5. Scratches glass very feebly. Yields easily to the knife.
- 6. Scratches glass easily. Yields with difficulty to the knife.
- 7. Does not yield to the knife. Yields with difficulty to the edge of a file.
- 8, 9, 10. Harder than flint or rock-crystal.

Convenient terms of comparison for degrees of hardness above No. 7 cannot be easily obtained; but that is of little consequence, as there are but few minerals which exhibit a higher degree; and these are readily distinguished by other characters.

<u>Specific Gravity</u>.—This is also a character of great value in the determination of minerals. The specific gravity of a body is its weight compared with the weight of an equal bulk of pure water. In order to ascertain the specific gravity of a mineral, we weigh the specimen first in air, and then in water. The loss of weight in the latter case exactly equals the weight of the displaced water, or, in other words, of a volume of water equal to the volume of the mineral : and the specific gravity of pure water, at a temperature of about 62°, being assumed to equal 1, or unity, it follows that the specific gravity of a mineral is obtained by dividing the weight of the latter in air by its loss of weight in water. Thus, if a = the weight in air, and w = the weight in water, G, or $sp.gr. = \frac{a}{a-w}$.

E.cample.—A piece of calcareous spar weighs 66 grs. in air, and 41 grs. when immersed in rain or distilled water. Hence its sp. gr. $=\frac{66}{66-41}=\frac{66}{25}=2.64.$

The weight of the mineral may be ascertained most conveniently, and with sufficient exactness for general purposes, by a pair of small scales such as are commonly called "apothecaries' scales." These may be purchased for a couple of dollars or even less. A small hole must be made in the centre of one of the pans for the passage of a horse-hair or silken thread (about four inches in length) furnished at its free end with a "slip-knot" or running noose to hold the specimen whilst this is being weighed in water. The strings of the perforated pan may also be somewhat shortened, but the balance must in this case be brought into equilibrium by a few strokes of a file on the under side of the other pan, or by attaching thinner strings to it. If grain weights be used

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onveniently, air of small These may all hole must a horse-hair its free end on whilst this pan may also be be brought of the other ights be used with this balance, the following will be required: 50 grs., 30, 20, 10, 5, 3, 2, 1, 0.5, 0.3, 0.2, 0.1.

As an application of specific gravity, apart from the employment of the character in the determination of minerals, it may be observed that the weight of masses of rock, heaps of ore, etc., may be readily ascertained by reference to this property. The length, breadth, and depth of the body being taken in feet and decimal parts of a foot, and these dimensions being multiplied together, we get the contents of the body in cubic feet. This value is then multiplied by 62.32, the weight in lbs. of a cubic foot of water. This gives the weight of an equal bulk of water, which must finally be multiplied by the average sp. gr. of the body. The weight of the latter is thus obtained in lbs. Dividing this weight by 2,000 gives the weight in American or Canadian tons; and by dividing it by 2,240, we get the weight in British tons.

• Relative <u>Malleability</u>.—Some few minerals, as native gold, native silver, sulphide of silver, native copper, &e., are malleable or ductile, flattening out when struck, instead of breaking. A few other minerals, as tale, serpentine, &e., are <u>sectile</u>, or admit of being cut by a knife; whilst the majority of minerals are brittle, or incapable of being cut or beaten out without breaking. In testing the relative malleability of a mineral, a small fragment should be placed on a little anvil, or block of steel polished on one of its faces, and struck once or twice by a light hammer. To prevent the fragment from flying off when struck, it may be covered by a strip of thin paper, held down by the forefinger and thumb of the left hand. Thus treated, malleable bodies flatten into dises or spangles, whilst brittle substances break into powder.

<u>Magnetism.</u>—Few minerals attract the magnet in their natural condition, although many do so after exposure to the blowpipe. (See below.) In trying if a mineral be magnetic, we chip off a small fragment, and apply to it a little horse-shoe magnet, such as may be purchased anywhere for a quarter of a dollar; or otherwise we apply the specimen to a properly suspended magnetic needle. In this manner many of the black granular masses which occur so frequently in our Gneissoid or Laurentian rocks, and in the boulders derived from these, may easily be recognised as magnetic iron ore.* Most specimens of this mineral (and also of magnetic pyrites) exhibit "polarity," or attract, from a given point, one end of the needle, and repel the other.

* The other dark-coloured cleavable masses, in these rocks, consist of mica, or more rarely of hornblende or tourmaline.

Tuste.—This is a very characteristic although limited property, being, of course, exhibited only by soluble minerals. In these, the taste may be saline, as in <u>Rock Salt</u>; or bitter, as in <u>Epsom</u> Salt; or metallic, as in Sulphate of Iron, and so forth.

B. CHEMICAL CHARACTERS.

The chemical characters of principal use in the determination of minerals comprise the phenomena developed by the action of acids, and those produced by the application of the blowpipe. Before referring to these characters, the reader should be familiar with certain chemical terms of common employment in Mineralogy.

A substance of any kind, whether of natural or artificial formation, must be either a simple or a compound substance. If the former, it cannot be decomposed or subdivided into more simple bodies by any process of art. If compound, on the other hand, a decomposition of this kind may be more or less readily effected. Thus, whilst from a piece of sulphur, copper, or iron, if pure, nothing but sulphur, copper or iron respectively, can be extracted, a piece of copper pyrites will yield all three of these substances-each, as before, resisting further subdivision. Hence sulphur, copper, and iron are regarded as simple substances, whilst copper pyrites is a compound body. These so-called "simple" substances, it must be understood, may not be, and probably are not, absolutely simple; but they are simple, id est, undecomposable, in the present state of science. They are often known as Elements. Up to the present time between sixty and seventy have been recognized, but many occur only in a few rare minerals. Some-oxygen, nitrogen, chlorine, fluorine, hydrogen, - exist in the free state as gases; two at ordinary temperatures are liquid; the rest are solid. Some few occur naturally, at times, in the free or simple state. These form the so-called "native substances" (as Native Sulphur, Native Platinum, Native Gold, &c.,) of Mineralogists. Others occur only in combination. Some have a remarkable tendency to attack and combine with other bodies. Oxygen, chlorine, fluorine, sulphur and arsenie, in reference to natural compounds, may be especially cited in this respect. The binary compounds formed by these elements may be more or less passive bodies or bases, or active bodies or acids, although in some cases a strict line of demarcation cannot be drawn between the two. The bases have their generic name always terminated by the monosyllable "ide." Thus oxygen, in forming a compound of this kind, produces

22

CHEMICAL CHARACTERS OF MINERALS.

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In these oxidized compounds, it will be observed, three elements are present. Thus, the mineral cyanite (a silicate,) contains aluminium, silicon and oxygen; and carbonate of iron contains iron, carbon and oxygen. Now if these bodies be chemically decomposed they separate into an oxidized base on the one hand, and into an oxidized acid on the other. In other words, the silicate cyanite yields alumina or oxide of aluminium and anhydrous silicic acid; whilst from carbonate of iron, oxide of iron and carbonic acid are obtained. Calcite or calcareous spar, in like manner, may be formed from, and decomposed into, lime or oxide of calcium, and carbonic acid. If the mineral be exposed to a red heat, carbonic acid is expelled in the form of an invisible gas, and lime remains behind; and if this lime be exposed to the atmosphere it will gradually absorb carbonic acid from the latter, and the original compound will again result. Certain theoretical considerations, however, rather lead to the inference that this is not the actual constitution of these substances, but that the base is really in the simple metallic state, whilst all the oxygen is combined with the other element, silicon, carbon, &c. Thus in the above examples it is supposed that metallic aluminium, iron, and calcium, respectively, are combined with a compound of silicon and oxygen, or earbon and oxygen, containing more oxygen than ordinary silicic or carbonic acids. Various arguments might be adduced both in support of and against this opinion; but as the former view of the composition of these bodies is the more simple of the two, and is still very generally followed, it has been thought advisable to adhere to it in a work of the present elementary character.

Action of Acids.—As a general rule, the use of acids may be dispensed with in the ordinary determination of minerals, or resorted to only as a confirmatory test, when the name of the substance has been ascertained by other means. A drop of acid serves, however, very conveniently, to distinguish carbonates from most other bodies, by the effervescence which is produced by the liberation of carbonic acid from these salts. The test acids chiefly used, are nitric acid, and chlorhydric

CHEMICAL CHARACTERS OF MINERALS.

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acid. These must be kept in well-stoppered glass bottles provided with glass caps, as their fumes soon destroy cork, and are otherwise highly corrosive and deleterious. For geological purposes (testing calcarcous rocks, &c.) strong chlorhydric acid diluted with about an equal volume of pure water, is principally used. The small bottle in which this is kept, may have a long stopper extending into the acid; and a little nest or wicker-work pocket may be provided for its reception near the upper edge of the specimen basket. In examining a mineral with an acid, the substance should be reduced, in ordinary cases, to a fine powder, and covered in a test-tube or small porcelain capsule with a few drops of the acid, the latter being subsequently warmed or brought to the boiling point over the flame of a small spirit lamp. The following are some of the principal effects produced by this treatment:

(a). Simple solution :- Example, gypsum, &c.

(b). Solution with effervescence and simultaneous evolution of a colorless inodorous gas:—Ex. carbonates generally. Some of these, as calc spar, malachite, &c., dissolve with effervescence in cold and more or less dilute acid; but others, as dolonite or bitter spar, and carbonate of iron, only effervesce in heated acid. Either acid may be used, except in the case of carbonate of baryta or stroutia; as with these minerals, strong chlorhydric acid forms an insoluble conting of chloride of barium or strontium, by which the further action of the acid is entirely prevented. If the acid be used in a diluted state, however, this effect is prevented, chlorides of barium and stroutium being readily soluble in water.

(c). Partial solution, with separation of a gelatinous residuum:—Ex. various silicates: these are said to "gelatinize in acids." Boiling chlorhydric acid is generally required to produce the effect. The gelatinous matter consists of silicic acid or silica. Some silicates (Vesuvian, Epidote, &c.), which do not gelatinize under ordinary conditions, exhibit the effect after fusion or strong ignition.

(d.) Partial solution, with separation of granular silica, ex. harmotome, labradorite, &c. Boiling chlorhydric acid must be used, and the mineral should be finely pulverized.

(c.) Oxidation and solution, or partial solution, with evolution of sulphuretted hydrogen, known by its fetid odour. Example—Sulphides generally. The effect is most readily produced by boiling the mineral in powder, with chlorhydric acid.

(f.) Oxidation and solution, or partial solution, without odour of sulphuretted hydrogen. Ex. red copper ore, native copper, native silver, and some other minerals, when treated with hot nitric acid. The acid gives up part of its oxygen to the dissolving mineral, and the portion of the acid, thus altered, escapes in ruddy fumes. Acid cupreous solutions are green or greenish-blue in

colour. A piece of polished steel or iron immersed in a diluted solution of this kind, becomes coated with metallic copper.

(g.) Solution, or partial solution, and production, with chlorhydric acid, of chlorine fumes. Ex. pyrolusite or black manganese ore, &c. The chlorine is, of course, derived from the decomposition of the acid. Care must be taken not to inhale its fumes.

(*k*.) Solution, or partial solution, with production of fluohydric acid in corrosive fumes. Example—Fluor spar, in powder, with hot sulphuric acid. The evolved funces corrode glass. The experiment should be performed in a platinum or lead vessel. If a piece of glass coated on its under side with a thin layer of wax through which a pattern has been traced, be laid over the vessel for a few minutes, and then removed and washed in warm water, the lines of the pattern will be found more or less deeply etched on the surface of the glass. Great eare must be taken to prevent the fumes being inhaled.

(i.) The substance may remain undissolved and unattacked. Example-Quartz, orthoelase, zircon, &e.

Application of the Blowpipe :---The blowpipe in its simplest form is merely a narrow tube of brass or other metal, bent round at one extremity, and terminating, at that end, in a point with a very fine orifice (fig. 26). If we place the pointed end of this instrument just



within the flame (and a little above the wick) of a lamp or common candles and then blow gently down the tube, the flame will be deflected to one side in the form of a long narrow cone, and its heating powers will be wonderfully increased. Many minerals, when held in the form of a thin splinter at the point of thane thus acted upon, melt with the greatest ease; and some are either wholly or

partially volatilized. Other minerals, on the contrary, remain unaltered. Two or more substances, therefore, of similar appearance, may often be separated and distinguished in a moment, by the aid of the blowpipe.

The blowpipe (in its scientific use) has, strictly, a three-fold application. It may be employed, as just pointed out, to distinguish minerals from one another: some of these being fusible, whilst others are infusible; some attracting the magnet after exposure to the blowpipe, whilst others do not exhibit that reaction; some imparting a colour to the flame, others volatilizing, and so forth. Secondly, the

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blowpipe may be ouployed to ascertain the general composition of a mineral; or the presence or absence of some particular substance, as copper, lead, iron, cobalt, manganese, sulphur, arsenic, and the like. Thirdly, it may be used to determine in certain special cases, the actual amount of a metallic or other ingredient previously ascertained to be present in the substance under examination.

In using the blowpipe, the mouth is filled with air, and this is forced gently but continuously down the tube by the compression of the museles of the cheeks and lips, breathing being carried on simultaneously by the nostrils. By a little practice this operation becomes exceedingly easy, especially in ordinary experiments, in which the blast is rarely required to be kept up for more than fifteen or twenty seconds at a time. The beginner will find it advisable to restrict himself at first to the attempted production of a steady continuous flame, without seeking to direct this on any object. Holding the blowpipe in his right hand, (with thumb and two outside fingers below, and the index and middle finger above the tube,) near the lower extremity, he should let the inner part of his arm, between the wrist and the elbow, rest against the edge of the table at which he operates. The jet or point of the blow-pipe is turned to the left, and inserted either into or against the edge of the flame, according to the nature of the operation, as explained below. After a few trials, when sufficient skill to keep up a steady flame has been acquired, the point of the flame may be directed upon a small splinter of some easily fusible material, such as natrolite or lepidolite, held in a pair of forceps with platinum tips.* Some little difficulty will probably be experienced at first in keeping the testfragment exactly at the flame's point; but this, arising partly from irregular blowing and partly from the beginner feeling constrained to look at the jet of the blow-pipe and the object simultaneously, is casily overcome by half-an-hour's practice. A small cutting of metallic lead or the supported on a piece of well-burnt soft-wood charcoal can be examined in a similar manner. In these experiments the beginner must be careful not to operate on fragments of too large a bulk. The smaller and more pointed the object submitted to the flame, the easier and more certain will be the experiment.

[•] If forceps of this kind cannot be procured, a pair of steel forceps with fine points, such as watchmakers use, may serve as a substitute. It will be advisable to twist some silk thread or ne twine round the lower part of these in order to protect the fingers. The points must be kept clean by a file.

In out-of-the-way places the common form of blowpipe described above is frequently the only kind that can be obtained. It answers well enough for ordinary experiments, but the moisture which collects in it by condensation from the vapour of the breath is apt to be blown into the flame. This inconvenience is remedied by the form of construction shewn in the annexed figures, in which the instrument consists of two principal portions, a main stem closed at one end, and a short tube fitting into this at right angles near the closed extremity. The



F16, 27, F16, 28, F16, 29, F16, 30,

short tube is also commonly provided with a separate jet or nozzle of platinum. In this case, the jet can be cleaned by simple ignition before the blow-pipe flame, or over the flame of the spirit lamp. In the variety of blowpipe known as "Black's Blowpipe," FIG. 27, the main tube is usually constructed of japanned tin-plate, and the instrument is

thus sold at a cheap rate. Mitscherlich's Blowpipe, FIG. 29. consists of three separate pieces which fit together, when not in use, as shewn in FIG. 28. This renders it as portable as an ordinary pencil-case. FIG. 30 represents Gahn's or Berzelius's Blowpipe, with a trumpet shaped mouth-piece of horn or ivory as devised by Plattner. This mouth-piece is placed, of course, on the outside of the lips. It is preferable to the ordinary mouth-piece, but is not readily used by the beginner. In length, the blowpipe varies from about seven-and-a-half to nine inches, according to the eye-sight of the operator.

In addition to the blowpipe itself, and the forceps described above, a few other instruments and appliances are required in blowpipe operations.* The principal of these comprise: a few pieces of platinum wire, three or four inches in length, of about the thickness of thin twine, to serve as a support in fusions with borax, &c. (see below); two or three small glass flasks, or, in default, a narrow test-tube or two, used chiefly for the detection of water in minerals (see below); a small

^{*} It will of course be understood, that merely a slight sketch of the application of the blow pipe is given in these pages. Hence only the more necessary operations, instruments, &c., are alluded to.

CHEMICAL CHARACTERS OF MINERALS.

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hammer and anvil, or piece of hard steel, half-an-inch thick, polished on one of its faces; a bar or horse-shoe magnet; a pen-knife or small steel spatula; a small agate pestle and mortar; spirit-lamp, &c.; and half-a-dozen turned wooden boxes or small stoppered bottles to hold the blowpipe reagents. These latter are employed for the greater part in the solid state, a condition which adds much to their portability, and renders a small quantity sufficient for a great number of experiments. The principal comprise : Carbonate of soda (abbreviated into carb. soda, in the following pages), used largely for the reduction of metallic oxides, and in testing for sulphur and sulphuric acid, manganese, &c., as explained below; Biborate of soda, or Borax, used principally for fusions on the platinum wire, many substances communicating peculiar colours to the glass thus formed; and Phosphate of soda and ammonia, commonly known as microcosmic salt or phosphor salt, used for the same purposes as borax, and also for the detection of silicates and chlorides, as explained further on. Reagents of less common use comprise: nitrate of cobalt (in solution); bisulphate of potash; black oxide of copper; chloride of barium; metallic tin; and a few other substances of special employment.

The effects produced by the blowpipe cannot be properly understood without a preliminary knowledge of the general composition and structural parts of Flame. If the flame of a lamp or candle, standing in a place free from draughts, be carefully examined, it will be seen to consist of four more or less distinct parts, as shown in the annexed diagram,



FIG. 31. A dark cone, *a*, will be seen in the centre of the flame. This consists of gases, compounds of carbon and hydrogen, which issue from the wick, but which eannot burn as they are cut off from contact with the atmosphere. A bright luminous cone surrounds this dark central portion, except at its extreme base. In this bright cone the carbon, or a portion of it, separates from the hydrogen of the gaseous compounds pumped up by the wick. The earbon becomes ignited in the form of minute particles, and these, with the liberated hydrogen and undecomposed gas,

^{FIG. 31.} are driven partly outwards, and partly downwards, or into the blue cup-shaped portion which lies at the base of the flame. At this latter spot, the carbon, meeting with a certain supply of oxygen, is converted into carbonic oxide, a compound of equal combining weights

of carbon and oxygen. Finally, in the flame-border or outer envelope, of a pale pinkish colour, only discernible on close inspection, complete combustion, *i. e.*, union with oxygen, of both gases, carbon and hydrogen, takes place. The carbon burns into carbonic acid, a compound of two combining weights of oxygen with one of carbon; and the hydrogen, uniting with oxygen, forms aqueous vapour. If a cold and polished body, for example, be brought in contact with the edge of a flame of any kind, its surface will exhibit a streak or line of moisture.

Now these different parts of flame, possess, to some extent, different properties. The dark inner cone is entirely neutral or inert. Bodies placed in it, become covered with soot or unburnt carbon. The luminous or yellow cone possesses reducing powers. Its component gases, requiring oxygen for their combustion, are ready to take this from oxidized bodies placed in contact with them. This luminous cone, however, in its normal state, has not a sufficient temperature to decompose oxidized bodies, except in a few special cases; but its temperature, and consequently its decomposing or deoxidizing power, becomes indirectly much increased by the action of the blowpipe, as shown below. The blue portion of flame possesses also reducing powers, but of comparatively feeble intensity, as the carbon is there able to obtain from the atmosphere a partial supply of oxygen. Finally, in the outer or feebly luminous envelope, in which complete combustion takes place, the flame attains its highest temperature; and, having all the oxygen it requires from the surrounding atmosphere, it exerts an oxidizing influence on bodies placed in contact with it, since most bodies absorb oxygen when ignited in the free air.

In subjecting a body to the action of the blow-pipe, we seek, (1) either to raise its temperature to as high a degree as possible, so as to test the relative fusibility of the substance; or (2) to oxidize it, or cause it, if an oxide, to combine with a larger amount of oxygen; or (3) to reduce it, either to the metallic state, or to a lower degree of oxidation. The first and second of these effects may be produced by the same kind of flame, known as an oxidating flame (or O. F), the position of the substance being slightly different; whilst the third effect is obtained by a so-called reducing flame (or R. F.), in which the yellow portion is developed as much as possible, and the substance kept within it, so as to be cut off from contact with the atmosphere.

CHEMICAL CHARACTERS OF MINERALS.



F10. 32.

yellow portion becomes obliterated. It forms a long narrow blue cone, surrounded by its feebly luminous mantle. The body to be oxidized should be held a short distance beyond the point of the cone, as in FIG. 32; but to test its fusion, it must be held in contact with this, or even a little within the flame. In this position many substances, as those which contain lithia, strontia, baryta, copper, &c., impart a erimson, green, or other colour to the outer or feebly luminous cone.



FIG. 33.

For the production of a reducing flame the orifice of the blowpipe must not be too large. The point is held just on the outside of the flame, a little above the level of the wick, as shown in FIG. 33. The flame in its deflected state, then retains the whole or a large portion of its yellow cone. The substance under

treatment must be held within this (although towards its pointed extremity) so as to be entirely excluded from the atmosphere; whilst, at the same time, the temperature is raised sufficiently high to promote reduction. As a general rule, bodies subjected to a reducing treatment should be supported on charcoal.

For ordinary experiments, such as testing the relative fusibility, &c., of minerals, the blowpipe may be used with the flame of a common candle. The wick of the candle should be kept rather short (but not so as to weaken the flame), and it should be turned slightly to the left, or away from the point of the blowpipe, the stream of air being blown along its surface. A lamp flame, or that of coal gas, gives a higher temperature, and is in many respects preferable. The wick-holder (or jet, if gas be used) should be of a rectangular form, with its upper surface sloping towards the left at a slight angle. Either good oil, or, better, a mixture of about 1 part of spirit of turpentine, or benzine, with 6 parts of strong alcohol, may be used with the lamp. If the

e seek, (1) ole, so as to it, or cause ; or (3) to oxidation. same kind tion of the obtained by v portion is nin it, so as An oxidating and fusion flame

is thus produced. The point of

the blowpipe is inserted well into

the flame of the lamp or candle

under use, so as almost to touch

the surface of the wick. The de-

flected flame is thus well supplied

with oxygen, and its reducing or

latter mixture be used, equal volumes of the two ingredients must be first well shaken up together, and then the rest of the alcohol added. If the wick crust rapidly, the turpentine will be in excess, in which case another volume of alcohol may be added to the mixture.

The following are some of the more general operations required in the examination of minerals by the blow-pipe. A few others of special employment are referred to under the Reactions of the more common Elementary Bodies, given on a subsequent page.

(1) The Fusion Trial:-In order to ascertain the relative fusibility of a substance, we chip off a small particle, by the hammer or cutting pliers, and expose it, either in the platinum-tipped forceps or on charcoal, to the point of the blue flame (Fig. 26, above). If the substance be easily reduced to metal, or if it contain arsenic, it must be supported on charcoal (in a small cavity made by the knife-point for its reception), as substances of this kind attack platinum.* In other cases, a thin and sharply pointed splinter may be taken up by the forceps, and exposed for about half-a-minute to the action of the flame. It ought not to exceed, in any case, the size of a small carraway seedand if smaller than this, so much the better. If fusible, its point or edge (or on charcoal, the entire mass) will become rounded into a bead or globule in the course of ten or twenty seconds. Difficultly fusible substances become vitrified only on the surface, or rounded on the extreme edges; whilst infusible bodies, though often changing colour, or exhibiting other re-actions, preserve the sharpness of their point and edges intact.

The more characteristic phenomena exhibited by mineral bodies when exposed to this treatment, are enumerated in the following table :---

(a) The test-fragment may "decrepitate" or fly to pieces. Example, most specimens of galena. In this case, a larger fragment must be heated in a test-tube over a small spirit lamp, and after decrepitation has taken place, one of the resulting fragments can be exposed to the blow-pipe flame as directed above. Decrepitation may sometimes be prevented if the operator expose the test-fragment cautiously and gradually to the full action of the flame.

(b) The test-fragment may change colour (with or without fusing) and become attractable by a magnet. Example, carbonate of iron. This becomes first red,

^{*} In order to prevent any risk of injury to the platinum forceps, it is advisable to use charcoal as a support for all bodies of a metallic aspect, as well as for those which exhibit distinctly coloured streak or high specific gravity.

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use charexhibit then black, and attracts the magnet, but does not fuse. Iron pyrites on the other hand becomes black and magnetic, but fuses also.

(c) The test-fragment may <u>colour the flame</u>. Thus, most <u>copper compounds</u> impart a rich green colour to the flame; compounds containing baryta, and many phosphates and borates, with the mineral molybdenite, colour the flame pale green; sulphur, sclenium, lead and chloride of copper colour the flame blue of different degrees of intensity; compounds containing strontia and lithia impart a crimson colour to the flame; some lime compounds impart to it a pale red colour; soda compounds, a deep yellow colour; and potash compounds, a violet tint.

(d) The test-fragment may become caustic. Example, carbonate of lime The carbonic acid is burned off, and caustic lime remains. This restores the blue colour of reddened litnus paper. It also imparts if moistened, a burning sensation to the back of the hand or other sensitive part.

(e) The test-fragment may take fire and burn. Example, native sulphur; common bituminous coal, &c.

(f) The test-fragment may be volatilized or dissipated in fumes, either wholly or partially, and with or without an accompanying odor. Thus, grey antinony ore volatilizes with dense white fumes; arsenical pyrites volatilizes in part, with a strong odor of garlic; common iron pyrites yields an odour of brinstone; and so forth. In many cases the volatilized matter becomes in great part deposited in an oxidized condition (on the charcoal. Antimonial minerals form a white deposit or incrustation of this kind. Zinc compounds, a deposit which is lemon-yellow whilst hot, and white when cold. Lead and bismuth are indicated by sulphur—or orange-yellow deposits. Cadmium by a reddish brown incrustation.

(g) The test-fragment may fuse, either wholly, or only at the point and edges; and the fusion may take place quietly, or with bubbling, and with or without a previous "intumescence" or expansion of the fragment. Most of the so-called Zeolites, for example, (minerals abundant in Trap rocks), swell or carl up on exposure to the blow-pipe, and then fuse quietly; but some, as Prelmite, melt with more or less bubbling.

(h) The test-fragment may remain unchanged. Example, Quartz, and various other infusible minerals.

(2) Treatment in the Flask or Bulb-tube (The Water Test) :---Minerals are frequently subjected to a kind of distillatory process by ignition in small glass tubes closed at one end. These tubes are of two general kinds. One kind has the form of a small flask, and is commonly known as a "bulb-tube." Where it cannot be procured, a small-sized test-tube may supply its place. It is used principally in testing minerals for water. The other kinds consist simply of narrow pieces of glass tubing, closed and sometimes drawn out to a point at one extremity. They are chiefly employed in testing for mercury and arsenic (see below). Our present description refers solely to the use
of the bulb-tube. Many minerals contain a considerable amount of water, or the elements of water, in some unknown physical condition. Gypsum, for example, yields nearly 21 per cent. of water. As the presence of this substance is very easily ascertained, the water test is frequently resorted to, in practice, for the formation of determinative groups, or separation of hydrous from anhydrous minerals. The operation is thus performed. The glass is first warmed gently over the flame of a small spirit-lamp to ensure the absence of moisture, and is then set aside for a few moments to cool. This effected, a piece of the substance under examination, of about the size of a small pea, is



placed in it, and ignited over the spirit-lamp, as shewn in the annexed figure. If water be present in the mineral, a thin film, condensing rapidly into little drops, will be deposited on the neck or upper part of the tube. As soon as the moisture begins to shew itself, the tube must be held in a more horizontal position, otherwise a fracture may be decensioned by the water flowing down and coming in contact with the hot part of the glass. A small spirit-lamp may be made by fitting a piece of glass tubing of about

an inch in length to serve as a wick-holder, through an orifice in the cork of a short, flat bottle. When the lamp is not in use, the wick should be covered by a glass or other cap to prevent the evaporation of the spirit. A mineral may also be examined for water, though less conveniently, by ignition before the blowpipe flame in a piece of open



Fig. 35.

tubing, as shewn in FIG. 35. To provent the tube softening or melting, a strip of platinum foil may be folded around it where the test-fragment rests. The latter is pushed into

its place by a thin iron-wire. The moisture condenses on each side of the test-matter.

(3) Treatment with Nitrate of Cohalt :- This operation is but rarely required. It serves, in certain cases, for the detection of alumina,

magnesia, oxide of zinc, and some few other substances; but it is not applicable to deeply coloured or easily fusible bodies, nor to such as possess a metallie lustre or coloured streak. A fragment of the substance, under treatment, is reduced by the hammer and anvil, and afterwards by the use of the agate mortar, to a fine powder. This is moistened with a drop of the cobalt solution (nitrate of cobalt dissolved in water), and the resulting paste is strongly ignited on charcoal by being held about an inch before the point of the flame, fusion being carefully avoided. Thus treated, alumina assumes on cooling a fine blue colour; magnesia (and the comparatively rare tantalic acid), a flesh-red tint; baryta, a dull brownish-red colour; oxide of zine, binoxide of tin, antimony oxides, a green colour. With other substances a grey, blueish-grey, brownish-black, or other indefinite coloration is produced, unless fusion take place, in which case a glass may be obtained, coloured blue by the dissolved oxide of cobalt.

(4) Roasting :- The principal object of this operation is the elimination of sulphur, arsenie, and certain other volatile bodies, from the mineral under examination; as these prevent the reduction of many substances to the metallic state, and also mask, to some extent, their other characteristic reactions. By roasting, the substance is not only deprived of sulphur, &c., but is also converted in the majority of instances into an oxidized condition. The operation is most readily . performed as follows. A small fragment of the mineral is reduced to powder. Some of this is made into a paste by moistening with a drop of water, and is spread over the surface of a piece of charcoal, or broken fragment of a porcelain evaporating dish or thin crucible. It is then ignited before the point of an oxidating flame (Fig. 32), the heat being kept low, at first, to prevent fusion. It is sometimes necessary to remove the ignited paste to the mortar, and to break it up again with a fine steel spatula (the end of a flattened wire, or knife-point), and renew the operation. When the roasting is terminated, the powder will present a dull earthy aspect, and cease to omit fumes or odour. It is then ready for operations 5 and 6, described below. By reducing the substance to powder before roasting, the risk of decrepitation and fusion is prevented, and the process itself is more efficiently performed.

Roasting is sometimes effected in a piece of open glass tubing as in Fig. 35—only the test object is placed near one end of the tube, and the tube itself is held in a more inclined position. Sulphur eliminated

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from bodies by this treatment, is converted into sulphurous acid (a compound of sulphur and oxygen, the latter taken up from the atmosphere); and arsenic forms arsenious acid, which deposits itself in the shape of numerous microscopic octahedrons on the cool sides of the glass near the upper part of the tube. Sulphurous acid in escaping from the open end of the tube is easily recognized by its odour (identical with that emitted by an ignited match), as well as by its property of changing the blue colour of a slip of moistened litmus paper to red. Autimonial compounds form a dense white uncrystalline sublimate.

(5.) Formation of glasses on platinum wire or charcoal:-This operation is one of constant utility in the determination of the constituents of minerals. The glasses, in question, are formed by the fusion of small portions of borax, phosphor salt, or carbonate of soda: the latter reagent, however, being only occasionally used. Most substances, dissolve in one or the other of these glasses before the blowpipe, and many communicate to them peculiar colours by which the nature of the test-matter is made known. If the matter to be tested contain sulphur or arsenic, it should be roasted before being subjected to the action of these fluxes. Metals and metallie alloys, as well as metallic oxides, chlorides, &c., of very easy reduction, must be examined on charcoal, but in other cases it is more convenient to employ a piece of platinum wire as a support. One end of the wire may be inserted into a cork or special handle, or, if the wire be from 21 to 3 inches in length, it may be held in the naked fingers, as platinum conducts heat very slowly. The other end is bent into a small loop or ear. This, when borax or phosphor-salt is used, is ignited by the blow-pipe flame, and plunged into the flux, the adhering portion of the latter being then fused into a glass. If a sufficient portion to fill the loop be not taken up at first, the process must be repeated. With beginners, the fused glass is often brownish or discoloured by smoke, but it may be rendered clear and transparent by being kept in ignition for a few moments before the extreme point of the flame, the carbonaceous matter becoming oxidized and expelled by this treatment. When carbonate of soda is used, a small portion of the flux must be moistened and kneaded in the palm of the left hand, by a knife-point or a small spatula, into a slightly cohering paste, which is placed on the loop of the wire, and fused into a bead. Whilst hot, the bead is transparent, but it becomes opaque on cooling. The portion of test-matter added to a glass or bead, formed

CHEMICAL CHARACTERS OF MINERALS.

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l:-This the conl by the of soda: lost subthe blowthich the be tested subjected s well as amined v a piece inserted uches in nets heat r. This, pe flame, eing then not taken the fused rendered ts before ing oxids used, a the palm ghtly cod into a baque on , formed by these reagents, must be exceedingly small, otherwise the glass may become so deeply coloured as to appear quite black. In this case, the colour may be observed by pinching the bead flat between a pair of forceps, before it has time to cool. It is always advisable, however, in the first instance, to take up merely a minute particle or two of the test-substance, and then to add more if no characteristic action be obtained. The glass, in all cases, must be examined first before an oxidating flame, and its colour observed both whilst the flux is hot, and when it has become cold; and, secondly, it must be kept for a somewhat longer interval in a good reducing flame (fig. 33), and its appearance noted as before.* With certain substances (lime, magnesia, &c.) the borax and phosphor-salt glasses become milky and opaque when saturated, or when subjected to the intermittent action of the flamethe latter being urged upon them in short puffs, or the glass being moved slowly in and out of the flame-a process technically known by the name of flaming.

The colours, &c., communicated to these glasses by the more commonly occurring constituent bodies, are shown in the annexed tabular view.

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Colour of Bead after exposure to an Oxidating Flame.	Compounds of:	Color of Bead after exposure to a Reducing Flame.
Violet or Amethystine		Colorless, if quickly cooled. Violet-red, if slowly cooled.
Violet-brown (whilst hot) Clear-brown (when cold)	} Niekel	.Grey and opaque.
Blue (very intense):	Cobalt	.Blue (very deep).
Green (whilst hot) Blue or greenish-blue (cold)	} Copper	More or less colorless whilst hot; brownish-red & opaque on cooling.
Green or blueish-green	Cobalt + Iron	.Green or bluish-green,
Green (dark)	{ Copper + Nickel { Copper + Iron) Brownish-red, opaque, on cool j ing.
Yellowish or reddish (hot) Yellowish-green (when cold	Chromium	.Emerald-green.
Yellow (whilst hot) Greenish-yellow (cold)	} Vanadium	{ Brownish (whilst hot). { Emerald-green (when cold).
Yellowish or reddish	Iron	.Bottle-green.
Yellowish or reddish Enamelled by flaming	} Uranium	.Green (black by flaming).

* The colour of the glass ought not, of course, to be examined by the *transmitted* light of the lamp or candle flame. Strictly, it should be observed by daylight.

(O, F.)		(R. F.)
Yellow (whilst hot) Pale yellowish (cold) Enamelled by flaming	Cerlum	Colorless or yellowish. Opaque-wbite, if saturated.
Yellow (hot) Colorless (cold) Enamelled by flaming	Titaninm	Yellow or yellowish-brown. Enamelled light-blue by flam- ing. V. under phosphor-salt, below.
Yellow (hot) Colorless (cold) Enamelled by flaming	- Tungstenum	Yellow, or yellowish-brown, Emmelled by finning, V. under phosphor-salt, below.
Yellow (hot) Colorless or yellowish (cold). Greyish and opaque by flaming	- Molybdenum ·	Brown or grey, semi-opaque, often with separation of black speeks, V. under phosphor-salt, below.
Yellow or yellowish-red (hot) Yellowish or colorless, and often opaline, when cold	Lead Bismuth Silver Antimony	(Grey and opaque on cooling; but after continued subjection to the flame, the glass becomes clear: the reduced metallic particles either collecting to- gether or volatilizing.
Yellowish (hot) Colorless (cold) Opaque-white when saturated.	- Cadmium	Colorless—the reduced metal being volatilized.
Colorless (permanently clear). Slowly dissolved	Aluminium Silicon Tin	Colorless: permanently clear. (Tin compounds dissolve in small quantity only. On char- coal, they become reduced to metal, especially if a little carb, soda be added to the glass).
Colorless. When saturated, opaque-white on cooling or- by flaming	Tantalum Zireconium Glucinum Glucinum Yttrium, &c Thorium, &c Thorium. Calcium Strontium Barium Lithium. Natrium Kalium	Colorless. When saturated, opaque-white on cooling or by flaming. See Reactions, below.

PHOSPHOR - SALT.

The glasses produced by the fusion of constituent bodies with this reagent are for the greater part identical with those obtained by the use of borax, although somewhat less deeply coloured as a general rule. The principal exceptions are the glasses formed in a reducing flame with compounds of Molybdenum, Tungstenum, and Titanium, respectively. The molybdenum glass presents, when cold, a fine green colour, and the tungstenum glass becomes greenish-blue. If the latter contain iron, the colour of the glass is changed to blood-red or brownishred. Titanium in the presence of iron gives a similar reaction; but when free

CHEMICAL CHARACTERS OF MINERALS.

from iron, the glass is yellow whilst hot, and violet-coloured when cold. Phosphor-salt is an important reagent for the detection of silica in silicates, as the silica remains for the greater part undissolved in the glass, in the form of a translucent flocculent mass, technically known as a "silica skeleton," the associated constituents being gradually taken up by the flux. A small amount of silica is also generally dissolved, but this is precipitated as the bead cools, rendering it semi-transparent or opaline. Phosphor-salt is likewise employed for the detection of chlorides, &c. (See below.)

CARBONATE OF SODA.

This reagent is principally used to promote the reduction of oxidized and other bodies to the metallic state, as explained under the description of that process. (Operation 6, below.) It is also of frequent employment as a test for sulphur in sulphides and oxidized bodies. (See under Reactions.) It is rarely used, on the other hand, for the formation of glasses on platinum wire, except as a test for the presence of manganese; although, when employed, in this manner, it serves to distinguish salts of the alkalies, and those of strontia and baryta, from all other salts: the alkalies, with baryta and stroutin, dissolving completely and rapidly in the bead, whereas lime, magnesia, alumina, and other bases, remain unattacked. Manganese compounds form by oxidizing fusion with this reagent a green glass, which becomes blue or bluish-green and opaque on cooling. A very minute amount of manganese may be thus detected. The delicacy of the test is increased by the addition of a small quantity of nitre, as this promotes oxidation; and if the substance contain much lime, magnesia, iron oxides, or other bodies more or less insoluble in carb-soda, it is advisable to add a little borax to the test-mixture. The blue or bluish-green bead thus produced, is technically known as a "turquoise enamel." Chromium compounds produce a somewhat similar reaction; but if the bead be saturated with silien or boracic acid, it will remain green in the latter case; while if the green colour result from the presence of manganese, a violet or amethystine glass will be obtained. Some other applications of carbonate of soda as a blow-pipe reagent will be found under the head of REACTIONS.

6. Reduction :—This term denotes the process by which an oxidized or other compound is converted into the metallic state. Some compounds become reduced by simple ignition; others require for their reduction the addition of certain reagents; and some, again, resist reduction altogether. The reduced metal is in some cases so highly volatile that it cannot be obtained except by a kind of distillatory process. In other cases, one or more fusible globules, or a number of minute infusible grains, are obtained in blowpipe operations. Reducible metals may be thus distributed into three groups, as shown (with omission of a few metals of rare occurrence) in the annexed Table :—

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- A. Yielding metallic globules:-Gold, Silver, Copper, Tin, Lead, Bismuth, Antimony.
- B. Yielding infusible metallic grains:-Platinum, Iron, Nickel, Cobalt, Molybdenum, Tungstenum.
- C. Yielding metallic vapours only, when treated on charcoal :--Mercury, Arsenic, Cadmium, Zinc.

A metal of the first group may be obtained, unless present in very small quantity, by a simple fusion of the previously roasted test-substance, with some carbonate of soda, on charcoal, in a good reducing flame (FIG. 33, above). In ordinary cases, metallic globules are rapidly produced by this treatment. By a little management the globules may be brought together so as to form a single large globule. This must be tested on the anvil as regards its relative malleability, &c. Gold, silver, copper, tin and lead are malleable; bismuth and antimony, more or less brittle. Gold and silver (if pure) retain a bright surface after subjection to an oxidating flame. Copper becomes covered with a black film, and tin with a white crust. Lead and bismuth volatilize more or less readily, and deposit on the charcoal a yellow coating of oxide. Antimony is rapidly volatilized with deposition of a dense white inernstation on the charcoal. It is not, of course always necessary to subject the test-substance to a previous roasting (Operation 4, above) but it is always safer to do so. Sulphur in most, and arsenic in all cases, must be driven off by this preliminary treatment before the actual process of reduction is attempted.

When the metal to be reduced belongs to the second group, or if the amount of fusible metal in the test-substance do not exceed 4 or 5 per cent., the operation is performed as follows. A small portion of the substance in powder—subjected previously to the roasting process, if it contain sulphur or arsenic—is mixed with 3 or 4 volumes of carbonate of soda (or neutral oxalate of potash, or a mixture of about equal parts of earb-soda and cyanide of potassium—the latter, it must be remembered, a highly poisonous substance), and the mixture is exposed on charcoal to a good reducing flame, until all the alkaline salt has become absorbed. Some more of this is then added, and the operation repeated until the whole or the greater part of the test-matter is also absorbed. The charcoal at this spot is finally separated by a sharp knife-point and carefully ground to powder in a small agate mortar or porcelain capsule, whilst a fine stream of water is projected upon it from time to time, until all the carbonaceous and other non-metallic

CHEMICAL CHARACTERS OF MINERALS.

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p, or if ed 4 or rtion of brocess, mes of about it must ture is lkaline nd the -matter d by a mortar l upon hetallic particles are gradually washed away. For this purpose, the mortar or capsule may be placed in the centre of an ordinary plate; and if the operator be not provided with a chemical washing-bottle, he may use a small syringe, or, still more economically, a simple piece of glass tubing, five or six inches in length and about the fourth of an inch in diameter, drawn out at one end to a point. This is filled by suction, and the water expelled, with the necessary force, by blowing down the tube. The metallic grains or spangles obtained by this process must be examined by the magnet. Those of iron, nickel and cobalt are magnetic. Sometimes, however, when but a trace or very small percentage of reducible metal is contained in the test-substance, its presence is only indicated by a few metallic streaks on the sides and bottom of the mortar. Metallic markings of this kind can be removed by a piece of pumice

Metallic compounds referable to the third group, yield no metal on charcoal, or by other treatment in open contact with the atmosphere. The presence of arsenic, however, is easily made known by the garlielike odour evolved during fusion with reducing agents (or alone) on charcoal. Cadmium and zinc may also be recognized by the oxidized sublime as which they deposit on the charcoal. The cadmium sublimate is reddisa-brown; the zine sublimate, lemon-yellow and phosphorescent whilst hot, and white when cold. Mercury forms no incrustation on charcoal; but its presence in any compound may be determined by reduction with carbonate of soda or iron-filings in a glass tube of narrow diameter. A small test-tube or piece of glass tubing closed at one end before the blowpipe, may be used for the experiment. The test-substance, in powder, mixed with 3 or 4 vols. of perfectly dry earb. soda, is inserted into the tube by means of a narrow strip of glazed writingpaper bent into the form of a trough, so as to prevent the sides of the glass from being soiled, and the mixture is strongly ignited by the spiritlamp or by the blowpipe flame. If mercury be present, a grey metallic sublimate will be formed near the upper part of the tube. By friction with an iron wire, or the narrow end of a quill-pen, &c., the sublimate may be brought into the form of fluid globules, which can be poured out of the tube, and which are easily recognized as metallic mercury.

7. Cupellation :-Gold and silver are separated by this process from other metals. The test-metal is fused with several times its weight of pure lead. The button, thus obtained, is exposed to an oxidating fu-

sion on a porous support of bone-ash, known as a cupel. The lead and other so-called base metals become oxidized by this treatment, and are partly volatilized, and partly absorbed by the bone-ash, a globule of gold or silver (or the two combined) being finally left on the surface of the cupel. For blowpipe operations, cupels are generally made by. pressing a small quantity of dry boneash into a circular iron mould, the atter being fixed, when presented to the flame, in a special support, consisting essentially of a wooden foot and pillar with three or four short cross-wires (between which the cupel-mould rests) at the top of the latter. Instruments of this kind cannot be obtained in remote places, but the process may be performed equally well by the use of a small iron spoon, of about half-an-inch in diameter. Enough bone-ash to fill this, is taken up in it, and warmed over the spirit-lamp or by the blowpipe flame. The spoon is then placed on the blowpipe anvil, and, whilst the smooth or unused end of the agate pestle (or other similar object, a glass button cemented to a cork, for example) is pressed firmly on the surface of the bone-ash, the handle of the spoon is moved three or four times from side to side. The surface of the cupel thus formed is then exposed for a few moments to the point of the flame, so as to render the bone-ash thoroughly dry; and if its smooth condition be in any way affected by this treatment, the pressure with the pestle is repeated. Two or three little spoons of this kind should be kept at hand for cupelling experiments; but in their default, a cupel may be made by pressing some dry bone-ash into a suitable eavity fashioned at the extremity of a cylindrical piece of pumice or well-baked elay, or even charcoal. The substance to be cupelled must be in the metallic state; if not in this condition, therefore, it must first be subjected to the reducing process described above. In actual assaying or quantitative operations, this process is modified in various ways, but in the present work, in which merely a brief outline of the use of the blowpipe is attempted, it would be out of place to enter into these details. The piece of test-metal, which may weigh about a couple of grains (or from 100 to 200 milligrammes) is wrapped in a piece of pure lead-foil of three or four times its weight, and the whole is exposed on the surface of the cupel to the extreme point of a clear oxidating flame. If the substance consist of argentiferous lead, as obtained from galena, &c., the addition of the lead-foil is of course unnecessary. Six or seven grains (or from 400 to 500 milligrammes) may be taken for the experiment: a beginner, at least, will not not find it advisable to operate on a larger quantity at one time. As soon as fusion takes place, the cupel must be moved somewhat farther from the flame, so as to allow merely the outer envelope of the latter, or the warm air which surrounds this, to play over the surface of the globule. By this treatment, the lead will become gradually converted into a fusible and erystalline slag. When this collects in large quantity, the position of the cupel must be slightly altered, so as to cause the globule to flow towards its edge, the surface of the lead being thus kept free for continued oxidation. When the globule becomes reduced to about a fourth or fifth of its original bulk, the process is discontinued, and the cupel set on the anvil to cool. This is the first or concentration stage of the process. Another cupel is then prepared and dried; and the concentrated globule being carefully separated from the slag in which it is imbedded -by breaking up the old cupel under paper on the anvil, or gently crushing it between a pair of pliers-is placed on this, and again subjected to the oxidizing influence of the flame. During this second part of the process, the flame is made rather to play on the surface of the cupel around the lead button, than on the button itself, by which a complete absorption of the oxidized lead is effected. The flame should be sharp and finely pointed, and urged down on the cupel at an angle of forty or forty-five degrees. Finally, if the test-metal contain gold or silver, a minute globule of one (or both) of these metals will be left on the surface of the bone-ash. By concentrating several portions of a test-substance, melting the concentrated globules together, again concentrating, and finally completing the cupellation, as small an amount as half-an-ounce of gold or silver in a ton of ore-or in round numbers, about one part in sixty-thousand-may be readily detected by the blowpipe.

During cupellation, the process sometimes becomes suddenly arrested. This may arise from the temperature being too low, in which case the point of the blue flame must be brought for an instant on the surface of the globule, until complete fusion again ensue. Or the hindrance may arise from the boneash becoming saturated, when a fresh eupel must be taken. Or it may be occasioned, especially if much copper or nickel be present, by an insufficient quantity of lead. In this latter case, a piece of pure lead must by placed in contact with the globule, and the two fused together; the cupel being then moved backwards from the flame, and the oxidating process again established.

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Reactions: — Certain reactions of the more commonly occurring constituents of mineral bodies have already been mentioned in illustration of the various operations given above. In the present place a few additional reactions are described, and the whole are arranged in systematic form.

A. DETERMINATION OF THE CHEMICAL GROUP TO WHICH A MINERAL MAY BELONG.

In the examination of a mineral by the blowpipe, it is advisable to look first to its general chemical nature—or, in other words, to determine the chemical group to which it belongs—and afterwards, to seek for the base or bases which it may contain. The more important chemical groups of natural occurrence, comprise : Sulphides, Arsenides, Chlorides, Fluorides, Oxides, Sulphates, Silicates, Carbonates, Borates, Nitrates, Phosphates, and Arseniates. The group of simple Oxides ean only be determined by negative characters, but the other groups are easily recognized by a few simple experiments.

Experiment 1. Fuse the substance, in powder, with 2 or 3 vols. of carb. soda and a little borax, in a good reducing flame, on charcoal.

This experiment serves directly for the detection of Sulphides, Sulphates, Arsenides, and Arseniates.

a. A strong odour of garlie is emitted :—Arsenides and Arseniates. The former possess a metallie aspect, and emit the garlie odour when ignited per se. The latter never exhibit a metallie aspect. As occuring in nature, arseniates are mostly of a green, blue, or red colour, depending on the nature of the base.

b. A reddish or dark mass is produced. This, when moistened and placed on a bright silver coin or on a glazed visiting card, forms a dark stain. The moistened mass smells also of sulphuretted hydrogen: *Sulphides* and *Sulphates*. The former possess a metallic aspect, or, if the lustre be non-metallic, the streak is always distinctly coloured.* With few exceptions, they emit an odour of burning brimstone (sulphurous acid) when ignited *per se*; and in the open tube, the evolved acid reddens moistened litmus-paper. (See Operation 4, above.) The natural sulphates do not possess a metallic aspect, and the streak is either colourless or pale green or blue. They do not omit the smell of brimstone when heated.

^{*} Certain specimens of Zine Blende are the only exceptions to this, so far at least as regards naturally occurring minerals, to which alone the statements of the text apply.

CHEMICAL CHARACTERS OF MINERALS.

Other results, if exhibited, may be noted down for after reference.

Remarks :—Reactions a and b are sometimes produced by the same mineral, from the simultaneous presence of sulphur and arsenic (Arsenical pyrites, Realgar, Orpiment, &c.) Reaction b is also produced by Selenides and Seleniates, but these are of exceedingly rare occurrence, and they evolve at the same time a strong odour of cabbage-water or decomposing vegetable matter.

Experiment 2. Fuse a solid particle of the test-mineral with phosphor-salt on platinum wire.

This experiment serves directly for the detection of Carbonates and Silicates.

a. The substance dissolves rapidly and with marked effervescence : -- Carbonates.

Note :--Sulphates, Phosphates, and various other compounds, also dissolve readily by fusion with phosphor-salt, but produce no effer-vescence.

Note :--- Other reactions that may ensue from this experiment, such as the coloration of the glass, &c., may serve to detect the base or bases in combination with the carbonic or silicic acid. These reactions, therefore, should be noted down for after reference.

Experiment 3. Dissolve a few particles of black oxide of copper in phosphor-salt on platinum wire, so as to form a strongly-coloured glass-(Or simply melt some of the salt in a loop of thin copper-wire.) To this, add the test-substance, in powder, and expose the whole to the point of the blue cone.

This experiment serves directly for the detection of *chlorides*. a. The fused bead is surrounded by a bright azure-bluc flame.

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Note :---The coloration is produced by the volatilization of chloride of copper. It ceases therefore, after a time, but may be renewed by more of the test-substance being fused into the bead. The rare *Bromides* and *Iodides* can also be distinguished by this experiment. The former produce a blue flame with green streaks and edges, the latter a bright emerald-green coloration.

Experiment 4. Moisten the substance, in powder, with a drop of sulphuric acid, and expose on platinum wire to the point of the blue flame.

This experiment serves for the detection of Phosphates and Borates, as these bodies impart, when thus treated, a clearly marked green colour to the flame-border. The borates communicate also a green colour-after previous treatment with a few drops of sulphuric acidto the flame of alcohol. The phosphates and borates of natural occurrence are without metallic aspect. All dissolve readily in borax and phosphor-salt before the blow-pipe. Many communicate a green colour to the point of the flame when strongly ignited, per se. It must not be forgotten, however, that certain other bodies, oxide of copper, baryta, &c., also colour the flame green. Phosphates may also be detected as follows :---Melt some of the substance in fine powder with about 3 vols. of earb. soda, on platinum wire, or in a small platinum spoon. Treat the fused mass with a few drops of boiling water (in a test-tube, or, better, in a small porcelain or platinum capsule, over the spirit lamp), decant the clear solution from the insoluble residuum, and place in it a fragment of nitrate of silver. This forms a canaryvellow precipitate with solutions of phosphates as thus produced. The excess of carbonate of soda may be decomposed by the previous addition of a drop of nitrie acid, but the formation of a little earbonate of silver merely renders the yellow phosphatic precipitate somewhat paler. The presence of silica might give rise to error; but if the substance be a silicate, its true nature will have been detected by Experiment 2.

Experiment 5. Heat a small portion of the substance, in powder, at the bottom of a test-tube, with a few drops of strong sulphuric acid.

This experiment serves for the detection of Fluorides and Nitrates.

a. The inside of the tube is more or less corroded, and also covered, where damp, with a deposit of silica :—*Fluorides*. The results are best seen by washing out the tube, and then drying thoroughly in the

CHEMICAL CHARACTERS OF MINERALS.

flame of the spirit lamp. The corrosion arises from the formation of a compound of fluorine and hydrogen which readily attacks silica, producing a volatile compound of fluorine and silicon. This is decomposed by water, with deposition of silica. The latter re-action may be seen on the damp sides of the glass, and still more distinctly if a piece of narrow tubing with a drop of water at the end (kept there by the pressure of the finger at the other extremity) be brought within the mouth of the test-tube. The deposit of silica adheres to the glass with great tenaeity.

b: Brownish or orange-coloured fumes (best seen by looking down the tube) are evolved :—*Nitrates.* The fumes possess the peculiar sweetish smell of nitrous acid. All nitrates of natural occurrence are readily soluble in water. They deflagrate when ignited on charcoal or in contact with other organic bodies.

B. REACTIONS OF THE MORE COMMON MINERAL BASES.

In many minerals, the so-called base-lead, for example, in sulphide of lead (galena), copper in red or black oxide of copper, baryta in carbonate of baryta, and so forth-may be easily recognized by the use of the blowpipe. This is especially the ease, when the base consists of a single and easily reducible metal or metallic oxide, such as silver. lead, copper. tin, &c., or where it imparts a colour to borax or other reagents, as in the case of copper, iron, cobalt, nickel, manganese, &c.; or forms a deposit on charcoal, communicates a colour to the flame, or exhibits other characteristic reactions. Even when several bodies of this kind are present together in the base, their recognition, as a general rule, is easily effected. Earthy and alkaline bases, when in the form of carbonates, sulphates, phosphates, fluorides, &c., can also be made out. in general, without difficulty, unless several happen to be present together, in which case it is not always possible, by the simple aid of the blowpipe, to distinguish them individually. When these bases are combined with silica, on the other hand, the blow-pipe alone is rarely sufficient for their detection. This, however, as far as practical purposes are concerned, is of little consequence.

A complete scheme for the detection of mineral bases by the blowpipe, does not fall within the province of the present work, but an arrangement of the more important of these bodies, in groups, founded on blowpipe characters, is given below. Before referring to these groups, the unpractised operator is recommended to subject the speci-

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men under examination to three or four simple experiments, and to note down the results. These experiments comprise :---1, Ignition in the bulb-tube, for detection of water. (This experiment may be omitted as a general rule, if the substance possess a metallic lustre.) 2, Treatment per se on charcoal or in the forceps (see Operation 1, page 32 above), the characters more especially to be looked for, being, coloration of the flame, formation of a coating on the charcoal, assumption of magnetism, &c. 3, Treatment (after previous roasting [Operation 4], if sulphur, &c., be present) with borax, phosphor-salt, and carb-soda, respectively: observing if the glass be coloured, if the substance dissolve entirely in it, if a reduction to metal take place, and so forth (Operations 5 and 6, above). These experiments will in general be sufficient to determine the nature of the base; but occasionally, certain special operations may be required in addition, such as testing with nitrate of cobalt, or examination for mercury in the closed tube, as described on a preceding page (Operations 3 and 6).

SECTION 1.—GIVING per se, OR WITH CARB. SODA, ON CHARCOAL, METALLIC GLOBULES OR METALLIC GRAINS.

Group 1. Yielding malleable metallic globules, without deposit on the charcoal.

Gold. Silver. Copper.

48

Gold is insoluble in the fluxes. Silver is not oxidized per sc, but retains a bright surface after exposure to an oxidating flame. Copper becomes encrusted on cooling with a black coating. It imparts a green colour to the flame-border; and forms strongly coloured glasses with borax and phosphor-salt : (green (hot) blue (cold) in O F; red-brown, opaque, in R F : see above). Gold and Silver may be separated from copper, &c., by fusion with lead, and subsequent cupellation (Operation 7). If gold and silver be present together, the bead is generally more or less white. By fusing it in a small platinum spoon with bisulphate of potash, the silver dissolves, and the surface of the globule becomes yellow. If the globule be flattened out into a disc on the anvil, before treatment with bisulphate of potash, the silver is more rapidly extracted. The sulphate of silver must be removed by treating the spoon, in a porcelain or platinum capsule, with a small quantity of water, over the spirit lamp. By evaporation, and fusion of the residuum with carb. soda on charcoal, metallic silver can be again obtained.

Group 2. Yielding infusible metallic grains, without deposit on the charcoal :

Platinum. Iron. Nickel. Cobalt.

Platinum is not attacked by the blowpipe fluxes. Iron, Nickel, and Cobalt, are readily dissolved by fusion with borax or phosphorsalt, producing a coloured glass (see under Borax, page 37, above.) These metals are also magnetic. As a general rule, if a substance become attractable by the magnet after exposure to the blowpipe, the presence of iron may be inferred, cobalt and nickel compounds being comparatively rare. The presence of cobalt is readily detected by the rich blue colour of the borax and phosphor-salt glasses, in both an oxidating and reducing flame; but if much iron be present also, the glass is blueish-green. With borax in the R. F., nickel compounds give reduced metal, and the glass becomes grey and troubled.

Group 3. Yielding metallic globules, with white or yellow deposit on the charcoal.

Tin. Lead. Bismuth. Antimony.

Tiv and Lead give malleable globules. The sublimate formed by tin, is white, small in quantity, and deposited on, and immediately around, the globule. The lead sublimate is yellow, and more or less copious. Bismuth and Antimony give brittle globules. The bismuth sublimate is dark yellow; the antimony sublimate, white, and very abundant. Lead imparts a clear blue colour to the flame-border; Antimony, a greenish tint. As a general rule, a yellow deposit on the charcoal may be regarded as indicative of the presence of lead;* whilst the emission of copious fumes, and deposition of a white coating on the charcoal, may be safely considered to indicate antimony. The coating or sublimate formed by Zine (see below), although white when cold, is lemon-yellow whilst hot.

SECTION 2.—REDUCIBLE; BUT YIELDING NO METAL ON CHARCOAL. (This arises from the rapid volatilization of the reduced metal.)

Group 1. Volatilizing without odour, and without formation of deposit on the charcoal.

Mercury.

For the proper detection of this metal, a small portion of the testsubstance in powder must be mixed with some previously dried carb-

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se, but Copper a green es with -brown, ed from Operaenerally n with globule on the s more reating ntity of he resitained.

^{*} Some lead compounds give *per se* a white or greyish sublimate; but if the test-substance be mixed with carb, soda, the sublimate is always yellow.

soda, and the mixture strongly ignited at the bottom of a small tube or narrow flask. If mercury be present, a grey sublimate will be formed. This will collect by friction with a wire, &c., into small metallic globules, which may be poured out of the tube.

Group 2. Volatilizing without odour, but forming a deposit on the charcoal.

Cadmium. Zinc.

The deposit produced by cadmium is dark brown or reddish-brown. That produced by zinc is lemon-yellow and phosphorescent whilst hot, and white when cold. If moistened with a drop of nitrate of cobalt and ignited, it becomes bright green.

Group 3. Volatilizing with strong odour of garlic. Arsenic.

See additional reaction under Operation 4, page 35, above.

SECTION 3.--- NOT REDUCIBLE BEFORE THE BLOWPIPE.

Group 1. Imparting a colour to borax.

Manganese. Chromium.

Manganese compounds impart, before an oxidating flame, a violet colour to borax; Chromium compounds, a clear green colour. See also under "Carbonate of Soda" page 39, above.

The rare metals cerium, uranium, &c., belong also to this group. Reference should also be made to iron, nickel, cobalt and copper, as the oxides of these metals, if in small quantity, might escape detection by the reducing process.

Group 2. Imparting no color to the fluxes. Slowly dissolved by borax, the glass remaining permanently clear.

Alumina.

Moistened with nitrate of cobalt and then ignited, this base assumes on cooling a fine blue color.

Group 3. Imparting no colour to the fluxes. Rapidly dissolved by borax, the glass becoming opaque on cooling or when flamed.

Magnesia. Lime.

Moistened with nitrate of cobalt, and ignited, *Magnesia* becomes pale-red in colour; *Lime*, dark-grey.

Group 4. Entirely dissolved by fusion with carb-soda. Baryta. Strontia. Lithia. Soda. Potash.

CHEMICAL CHARACTERS OF MINERALS.

Baryta compounds impart a distinct green colour to the point and border of the flame. Strontia and Lithia colour the flame deep carmine-red. The erimson coloration is destroyed in the case of strontia if the substance be fused with chloride of barium. Soda colours the flame strongly yellow. Potash communicates to it a violet tint; but this colour is completely masked by the presence of soda, unless the flame be examined through a deep blue glass.

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PART II.

THE MINERALS OF CENTRAL CANADA.

The preceding sub-division of this work is of a purely introductory character, explanatory of the more common properties possessed by minerals in general, and of certain technical terms employed in mineralogical definitions. In the present Part, the Minerals of Central Canada, comprising the Provinces of Ontario and Quebec, are classified and described. In these descriptions, in accordance with the stated plan of the work, minute chemical and crystallographic details are purposely omitted : details of this kind being obviously out of place in a work intended for general use. Localities also, except in a few instances, are only stated generally, *i. e.*, without precise reference to lots and concessions; but an attempt is made in all cases to give the localities in systematic order, based, as much as possible, on their geological relations.

The classification, adopted in the work, is founded essentially on composition, as being the most convenient for practical reference. It is preceded, however, by an Analytical Key, by means of which the name and place of any mineral described under the Classification proper, may be easily arrived at; and a Simplified Key or Tabular Arrangement, including minerals of common occurrence only, is also given for the same purpose. The method of application is explained fully at the end of the principal key: a certain knowledge of technical terms; and of the more common properties of minerals, as explained in the preceding division of the work, being of course supposed on the part of the reader.

ANALYTICAL KEY,

By which the name of any Canadian Mineral may be easily ascertained.

NOTE.—In this Key, minerals of common or extensive occurrence are denoted by the name being printed in large capitals, and minerals of tolerably common occurrence, by the use of small capitals. Names in ordinary type, refer to minerals of rare occurrence or obscure

character: so far, at least, as regards the presence of these minerals in Canada. The initials BB, signify "before the blowplpe." The number placed within brackets after the name of a mineral, refers to the position of the substance in the classification proper, in which its description is given, at the end of the key.

1 {	Aspect metallic or sub-metallic 2 Aspect non-metallic (<i>i. e.</i> vitreous, stony, &c.)
2 {	Occurring in detached grains or scales
3 {	Soiling, or marking on paper
4 {	Yielding by trituration a white or light-grey powder. MICA (Nos. 77–78.) Not yielding a white powder by trituration
5 {	Colour, yellow. Fusible
6 {	Hardness sufficient to scratch glass
7 {	BB, emitting fumes, or odour of garlic or brimstone
8{	Colour, light brass-yellow
9	In cubes or other Monometric Crystals (p. 14), or massive IRON PYRITES (No. 20.) In pointed, Prismatic Crystals of the Trimetric System (p. 16), mostly arranged in curved rows Marcasite or Prismatic Pyrites* (No. 21.)
10 {	BB, easily fusible
11 {	Streak-powder, dull-red SPECULAR IRON ORE (No. 29.) Streak powder, black or brown 12
12 {	Strongly magnetic MAGNETIC IRON ORE (No. 31.) Not (or very feebly) magnetic 13
13 {	Streak, black, brown, reddish brown, or greenish
14	Black, sub-metallic. BB, with phosphor-salt in R. F., a fine green glass CnROMIC IRON ORE (No. 33.) Black, sub-metallic. BB, with phosphor-salt in R. F., a red-brown glass TITANIFEROUS IRON ORE (No. 30.)

^{*} Iron Pyrites and Marcasite have exactly the same composition (Snlphur 53.3, Iron 46.7), but their crystal forms are quite distinct. Iron Pyrites is very abundant; Marcasite, in Canada, comparatively rare. Marcasite is especially prone to decomposition; specimens are thus often coated with a greenish-white efflorescence, or minute hair-like crystals, of sulphate of iron.

ANALYTICAL KEY.

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15 { More or less distinctly malleable 16 Not malleable 20
16 BB, no fumes, or deposit on charcoal
17 Colour, yellow (soft)
18 (BB, on charcoal, a copious yellow incrustation
19 { Colour, lead-grey. Perfectly malleable Lead (No. 7.) Colour, tin-white. Slightly malleable Bismuth (No. 8.)
20 Structure distinctly sealy or micaceous, the substance admitting of sepa- ration into thin leaves, plates, or scales
21 { Marking on paper. Streak, black
21 bis. { Not attacked by acids MUSCOVITE or POTASH-MICA (No. 77.) Decomposed (in powder) by sulphuric acid PHLOGOPITE or MAGNESIA MICA (No. 78.)
22 Colour, black. BB, not dissolved by fluxes GRAPHITE (No. 1.) Colour, lead-grey. BB, giving sulphur-reaction (see p. 44) with earb- soda and borax
23 { Attracting the magnetic needle. Colour, brownish-yellowMAONETIC PYRITES (No. 19.) Not affecting the magnetic needle
24 BB, easily fusible (with or without previous decrepitation)
25 { BB, a magnetic globule
26 { Occurring in the form of minute actual crystals or fibres. Millerite (No. 18.) Massive, or not in actual forms
27 Colour, brass-yellow (sometimes with iridescent tarnish). Streak, greenish-black
28 { C, tin-white, pale-red, or yellowish
29 BB, strong odour of garlic Arsenical Nickel Ore (No. 17.) BB, volatilizable with deposition of white coating on the charcoal Native Antimony (No. 9.) BB, volatilizable with deposition of dark-yellow coating on the charcoal
Native Bismuth (No. 8)

	30 BB, on charcoal, yellow or dense-white incrustation
	COPPER GLANCE (No. 14.) 31 Fusible, per se, in candle-flame. Structure fibrous or fine granular 32
	(Breaking into rectangular or cubical fragments. Very heavy GALENA (No. 12.)
	32 BB, on charcoal (with carb-soda), a dense white incrustation BB, on charcoal (with carb-soda), a yellow (or yellow and white) incrus-
	(tation
;	33 { Soluble in hot nitric acid Bismuth Glance (No. 24.) Converted by nitric acid into a white powder Plumbiferous Antimony Ore (No. 35, note.)
	34 Lustre distinctly metallic; streak greyish-black; mostly fibrous or acicular
	Soluble or partially soluble in water. Taste bitter or metallic. Occurring chiefly as an efflorescence or incrustation
	36 { BB, with borax, a coloured glass or bead
	37 Solution giving a deep blue precipitate with red or yellow "prussiate of potash."*Green Vitriol (Sulphate of Iron) (No. 100.) Solution giving a greenish-white precipitate with "yellow prussiate." Sulphate of Nickel (No. 101.)
	38 BB, with nitrate of cobalt, a blue mass after ignition (see p. 34.) Alum (No. 102.)
	(BB, with intrate of cobalt, a pale-red massEpsomite (No. 99.)
	39 Colour yellow or yellowish-brown
	40 { BB, taking fire and burning with blue flameSulphur (No. 2.) BB, not inflammable
	41 { BB, becoming black and magnetic
	42 { Occurring in thin crusts on bituminous shale Humboldtine (No. 108.) Occurring under other conditions
	Colour, red. BB, becoming magneticRED OCHRE and SCALY RED
	C. black, dark-brown, blue, or green 44
	44 { C. black or dark-brown

* As the iron is always partly peroxidized, a blue precipitate is produced by either of these reagents.

ANALYTICAL KEY.

45 BB, inflammable
(p. 39.)
46 { Colour, blue
(Effervescing in acids: BB, reactions of Copper (p. 37.), Blue Carbonate
47 BB, rendered magneticVivianite (Phosphate of Iron (No. 104.)
48 { Hardness sufficient to scratch window-glass distinctly
49 { Fusible or partially fusible, per se
$50 \begin{cases} \text{Sp. gr.} = 3.0 \text{ or } less. (Colour, mostly pale.)$
51 { Yielding water by ignition in bulb-tube (see p. 34)
 Fnsible on thin edges, only. C. dark-green Chloritoid (No. 81.) Easily fusible. C. light green, greenish-white PREHNITE (No. 67.) Easily fusible. C. peach-blossom redWilsonite: var. of Scapolite (No. 63.)
53 { Easily fusible
(White, red, &c. In masses with smooth rectangular cleavage
ORTHOCLASE (No. 57.) Cleavage not rectangular. Cleavage planes faintly striated
White, reddish, &c. BB, imparting a yellow colour to the flame
Grey, often with coloured reflections LABRADORITE (No. 58.)
56In rhombic dodecahedrons or trapezohedrons (p. 14), or in imbedded granular masses mostly of a red colour
57 In black, brown, or green triangular prisms (often broken and disjointed), or in fibres with triangular cross fracture TOURMALINE (No. 46.) In other forms
(In dimetric (square prismatic) crystals (p. 15). Sp. gr. 3.5 or more
58 Idocrase (No. 48.) 59
(Fusible into a globule or rounded mass AMPHIBOLE (No. 52.)
59 Fusible on the surface, only, into a dull slag or scoria
(In flat wedge-like crystals, mostly dark-brown or yellowish
60 { In green fibrous masses and long prismatic crystals EPIDOTE (No. 51.)
61 { Streak-powder, white, or greyish in dark specimens

: (No. 14.) .r 32 . (No. 12.) . (No. 25.)

..... 31

e (No. 25.) incrus-..... 33

e (No. 24.) timony . 35, note.)

ous or .e (No. 35.)

eaction, E (No. 13.)

l (No. 101.) (No. 102.) e (No. 99.)

40 43 ur (No. 2.) 41 42

е (No. 37.) (No. 108.) е (No. 34.)

RED 8 (No. 29.) 44

her of these

..... 45 46

$62 \begin{cases} \text{Sp. gr. under 2.8; H} = 7.0; \text{ vitreous ; fusible with carb-soda into a} \\ \text{clear glass.} & \text{QUARTZ (No. 43.)} \\ \text{Sp. gr. over 3.0} & & \text{63} \end{cases}$
63 { Harder than quartz
(Crystallization, Hexagonal; $H = 9.0$; sp. gr. $3.8 - 4.1$ Corundum
$ \begin{cases} \text{Crystallization, Octahedral (Monometric System); } H = 8.0; \text{ sp. gr.} \\ 3.5 - 4.5. \\ \text{Crystallization, Square-pyramidal (Dimetric System); } H = 7.5; \text{ sp. gr.} \\ 4.0 - 4.7. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.1 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.0 - 7.5; \text{ sp. gr. } 3.5 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.5 - 7.5; \text{ sp. gr. } 3.5 - 4.5. \\ \text{Crystallization, Rectangular-prismatic: } H = 7.5 - 7.5; \text{ sp. gr. } 3.$
(3.2Andalusite (No. 45.)
[Red or Orange; Lustre inclined to semi-metallic; sp. gr. $4.1 - 4.3$
65 Yellow; in small granular masses (mostly with graphite in crystalline limestone); sp.gr. 3.1 — 3.2
66 { Strongly magnetic
67 { Streak-powder, black or brown
68 BB, with borax, an emerald-green glassCuromic Iron Ore (No. 33.) BB, with borax, a dingy-green glassTITANIFEROUS IRON ORE (No. 30.)
69 { BB, fusible
 BB, easily dissolved by borax or phosphor-salt, the saturated glass becoming opaque on cooling or when flamed (p. 37)
71 { BB, yielding sulphur-reaction with carb-soda and silver foil (p. 44) 72 BB, no sulphur-reaction with carb-soda, &c. Mostly in cubical crystals FLUOR SPAR (No. 106.)
(Yielding a large amount of water by ignition in bulb-tube
72 { GYPSUM (No. 98.) { No water on ignition
BB, imparting an apple-green tint to the flame-border
BARYTINE (No. 96.) BB, imparting a carmine-red colour to the flame-border CELESTINE (No. 97.)
74 BB, imparting a green tint to point of flameDatolite (No. 68.) BB, imparting a yellowish or indistinct colour to the flame
75 { BB, fusible quietly
76 Crystallization, Dimetric (p. 15) Apophyllite (No. 76.) Crystallization, Trimetric (p. 16) Thomsonite (No. 70.)

ANALYTICAL KEY.

43.) . 63 . 64 . 65 m . 41.) r. . 42.) r. . 42.) r. . 42.) . 45.)

. 40.) ne . 56.) r. . 55.)). 31.) .. 67 .. 68). 29.**)** o. 33.) o. 30.) .. 70 .. 77 **188** .. 71 a .. 74 ... 72 . 106.)

o. 98.)

. . 73

0, 96.)

o. 97.)

o. 68.)

o. 75.)

... 76

io. 76.) io. 70.)

77 BB, very easily dissolved by borax or phosphor-salt, the saturated glass becoming opaque on cooling
78 BB, with carb-soda and silver foil (p. 44) yielding strong sulphur-reaction Light coloured varieties of ZINC BLENDE (No. 13.) BB, no sulphur-reaction
$ \begin{array}{l} H = 5.0. \text{Soluble (in powder) without effervescence in heated nitric} \\ \text{or hydrochloric acid} \dots \dots$
80 { Soluble with strong effervescence in cold acids CALCITE (No. 88.) Effervescing only in heated acids DOLOMITE (No. 90.) MAGNESITE (No. 91.)
81 { Yielding merely traces of water on ignition (page 34)
82 Foliated or scaly. Thin leaves, elastic. Lustre, mostly pseudo-metallic MICAS (Nos. 77 and 78.) Foliated or compact. Not elastic. Soapy to the touch. No pseudo- metallic lustre
83 { Fibrous, in soft silky masses
84 { Foliated or scaly
S5 { In soft nacreous scales of light colour. Becoming blue by ignition with nitrate of cobalt (page 34) PHOLERITE (No. 84.) In dark-green foliated or fine scaly masses. Mostly fusible on the edges CHLORITE (No. 80.)
86 Assuming a pale-red colour by ignition with nitrate of cobalt (page 34) SERPENTINE (No. 83.) Assuming a bright-blue colour by ignition with nitrate of cobalt (page 34) PINTE (No. 85.)

APPLICATION OF THE ANALYTICAL KEY.

The method of employing the above Key is shewn in the following example. Let the reader be supposed to have a massive piece of magnetic pyrites, of the name and nature of which he is ignorant. Turning to the first bracket of the Key, he finds:

As the substance possesses a metallic aspect or lustre, he turns to bracket 2. There he finds:

As the specimen is not in the form of loose grains or scales, but in that of a solid mass, he turns to bracket 6, which reads :

As the mineral is not hard enough to scratch glass, bracket 15 must be referred to, which reads:

As the substance is not malleable—a small piece breaking readily into powder under the hammer-the inquirer turns to bracket 20. He there finds:

Structure distinctly scaly or micaceous, the substance admit-

ting of separation into thin leaves, plates, or scales 21 Structure not micaceous or scaly.. { Marking or soiling 21 Not marking or soiling 23 20 <

As the mineral under investigation does not present a scaly or micaceous structure, and does not soil the hands or leave a mark on paper, reference is made to bracket 23. This reads :

 Λ small particle or two being chipped off the specimen, and tried by a common magnet—or the entire specimen being held near a magnetic needle-attraction is found to ensue; hence the substance is shewn to be Magnetic Pyrites, No. 19 of the classified series described in the following pages. By reference to the description there given, the various physical and chemical characters of the substance, its percentage, composition, localities, &c., may at once be ascertained. In using the Key, care must be taken to pass regularly from one indicated bracket to the other, without attempting, on account of foregone conclusions respecting the nature of the substance, to jump over any of them, or to refer to others than those actually indicated. If this be not attended to, errors and confusion may easily arise.

As the above Key contains a good many minerals of rare or comparatively exceptional occurrence, the beginner may frequently avoid unnecessary trouble, in making out the name of an unknown substance, by consulting in the first instance the annexed simplified Key, in which Canadian minerals of common occurrence are alone included. Reference should then be made, for confirmatory proofs, to the complete description of the species indicated by the Key.

SIMPLIFIED KEY.

61

A TABULAR GROUPING OF CANADIAN MINERALS OF COMPARA-TIVELY FREQUENT OCCURRENCE.

* Aspect Metallic or Sub-Metallic.

Malleable

Not Malleable.

- ** Hard enough to seratch glass distinctly. Not scratched, or very slightly seratched, by the point of a knife.
 - (a) Pale brass-yellow (Often in cubes) :- Iron Pyrites (No. 20).
 - (b) Tin-white, or between silver-white and pale-grey (Emitting a garliclike odour on ignition):—Arscnical Pyrites (No. 22).
 - (c) Steel-grey; powder, dull-red :- Specular Iron Ore (No. 29).
 - (d) Iron-black; powder, black; strongly magnetic :- Magnetic Iron Ore (No, 31).
 - (c) Iron-black; powder, black or brown; feebly or non-magnetic:— Titaniferous Iron Ore (No. 30); also Chromic Iron Ore (No. 33).

*** Too soft to seratch glass. Easily scratched by a knite-point.

- (a) Colour, yellow :- Native Gold (No 3).
- (b) Colour, silver-white (but often with dark tarnish):-Native Silver (No. 5).
- (c) Colour, black :- Silver Glance (No. 11).
- (d) Brownish-yellow; slightly magnetic: -Magnetic Pyrites (No.19).
- (c) Brass-yellow (often with variegated tarnish); streak, greenish black:—Copper Pyrites (No. 16).
- (f) Reddish, with purple tarnish; streak, greyish-black:—Purple Copper Pyrites (No 15).
- (g) Dark-grey (often with blue or green tarnish); cleavage indistinet:—Copper Glance (No. 14).
- (h) Lead-grey; breaking readily, with rectangular cleavage, into cubical fragments; very heavy:-Galena (No. 12).
- (i) Light lead-grey; in soft, scaly masses; marking:-Molybdenite (No. 23).
- (k) Black; soft, mostly in scaly or leafy masses; marking and soiling:-Graphite (No. 1).
- (1) Lustre, metallie-pearly; brown, black, silvery-white, &c. In foliated or scaly masses with white or light streak; easily separated into thin leaves:—Mica, including chiefly Muscovite (No. 77) and Phlogopite (No. 78).
- + Aspect : vitreous, stony, or earthy.

† Hard enough to scratch glass distinctly. Not scratched by a knife-point.

- (a) Vitreous: colourless, amethystine, brownish, &c. Mostly in hexagonal prism-pyramids, or in groups of sharply-pointed crystals; otherwise massive. No lamellar structure. (Infusible):—Crystalline Quartz, including Rock Crystal, Amethyst, Smoky Quartz, &c. (No. 43).
- (b) Vitreous or stony. In nodular masses of grey, red, bluish, and . other colours, two or more tints being often present together in spots or bands. (Infusible):—Calecdonic Quartz, including the various Agates, &c. (No. 43).

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- (c) Stony or pearly-vitreous. White, grey, rcd, green, &c. Mostly in lamellar masses, which cleave easily in several directions, presenting smooth and somewhat pearly cleavage planes. Fusible, but as a general rule not very easily: the point of a thin splinter is soon rounded or vitrified, however, in a properly sustained flame):—The various Feldspare, including more especially Orthoclase or Potash-Feldspar (No. 57); Albite or Soda-Feldspar (No. 58); and Labradorite or Lime-Feldspar (No. 60).
- (d) Vitrcous. Greenish-white or pale-green. Mostly in botryoidal masses with crystalline surface. Easily fusible. Yielding a little water in the bulb-tube:—*Prehnite* (No. 67).
- (e) Dark or bright-red, brown, &c. Mostly in rhombic dodecahedrons or in small rounded masses. Fusible. (Sp. gr. over 3.4):-Garnet (No. 47).
- (f) Black or dark-brown. Mostly in triangular (and often broken) prisms, or in acicular or fibrous groups. Easily fusible:—*Tour*maline or Schorl (No. 46).
- (g) Black, brown, green, greenish-white or colourless. In small crystals (mostly imbedded in crystalline limestone, or otherwise in trap rocks), and also in clearable and granular masses. Fusible:— Pyrozene (including Augite, &c.) No. 53; and also Amphibole, (including Hornbleude, &c.) No. 52.

+++ Too soft to scratch glass. Easily scratched, or cut, by the point of a knife.

- (a) White, grey, &c. Effervescing in cold acids. Infusible:-Calcite (No. 88).
 - (b) White, brownish, &c. Effervescing only in heated acids-Infusible:—Dolomite (No. 90); also Magnesite (No. 91).
 - (c) Green, reddish brown. Mostly in six-sided prisms with rounded edges. Infusible, or nearly so. (H = 5.0):-Apatite (No. 103).
 - (d) Violet-blue, green, greyish, &c. Mostly in cubes. Fusible:— Fluor Spar (No. 106).
 - (e) White, yellowish, greyish, pale-red, &c. Mostly in cleavable masses. Very heavy (sp. gr. = 4.4 - 4.7. Fusible, tinging the flame pale-green:-Heavy Spar (No. 96).
 - (f) White, pale-blue, &c. Mostly in cleavable masses or small crystals in limestone rocks. Fusible, tinging the flame carmine-red:—*Celestine* (No. 97).
 - (g) White, greyish, &c. Scratched by the nail. Fusible, becomcoming at once opaque and dull-white when held at the edge of a candle-flame: yielding a large amount of water by ignition in the bulb-tube:—Gypsum (No. 98).
 - (h) White, greenish, green and brown, &c.; often mottled. Very sectile, and more or less soapy to the touch:-Tale and Steatite (No. 82). Also, Serpentine (No. 83).
 - (i) Dark or light-green, scaly or earthy:-Chlorite (No. 80).
 - (k) Pearly-white, brown, black, &c. In leafy and scaly masses with more or less pseudo-metallic lustre. Splitting into thin plates:—The various Micas, including more especially: Muscovite or Potash-Mica (No. 77), and Phlogopite or Magnesia-Mica (No. 78).

Streak, white, or very faintly coloured.

Not yielding water by ignition in the bulb-tube.

Yielding water, or distinct traces of nioisture, by ignition in the bulb-tube.

PRINCIPLES OF CLASSIFICATION.

Streak, distinctly coloured.

- (!) Streak, pale-brown. Colour, brown, black, yellow, &c. Mostly in indistinct crystals or small cleavable masses :- Zinc Blende (No. 13).
- (m) Streak dull or bright-red. Colour brick-red. Magnetic after ignition:—Red Ochre and other varieties of Red Iron Ore (No. 29).
- (n) Streak brownish-yellow. C. dark or light-brown. Magnetic after ignition, and yielding water in the bulb-tube:— Yellow Ochre and other varieties of Brown or Bog Iron Ore (No. 34).
- (o) Streak, pale-green; colour, green:-Malachite (No. 94).
- (p) Streak, pale-blue; colour, blue. Mostly in crusts or earthy masses:— Blue Carbonate of Copper (No. 95). Also Phosphate of Iron (No. 104).

SYSTEMATIC ARRANGEMENT OF MINERALS.

Mineral bodies are characterized partly by composition, and partly by physical properties. Composition alone, is not sufficient in all cases to define or individualize a mineral species, as certain substances -Carbon, for instance, in graphite and the diamond; Carbonate of Lime, in Calcite and Arragonite-may occur in Nature under two or more distinct physical conditions. On the other hand, a close resemblance, in general aspect and other physical characters, may be exhibited by minerals of very dissimilar composition. Minerals have thus a double nature, so to say-chemical and physical : the one frequently in apparent opposition to the other; and in this lies the difficulty of framing a satisfactory classification of minerals. A system of arrangement based on chemical composition, although unavoidably artificial in many of its details, is especially convenient for practical reference, and on the whole is perhaps best suited to meet the requirements of the general student. A system of this kind is adopted, therefore, in the present work. It comprises five leading groups or classes. First, a group of simple or so-called Native Substances, as Native Sulphur, Native Gold, Native Silver, &c., the naturally occurring elementary bodies of chemical language (See under "Chemical Characters" in Part I). Secondly, a group of Sulphides and Arsenides, or compounds of sulphur, or of arsenic, with various metals : galena, iron pyrites, arsenical pyrites, are examples. Thirdly, a large group of oxygenized compounds, including Simple Oxides, as red iron ore, &c., and various so-called oxygen-salts, as Silicates, Carbonates, Sulphates, and the like. (See explanation of Chemical Terms in Part I. Also the explanatory remarks prefixed to the different groups and sub-divisions, in the

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following pages.) Fourthly, a group of Fluorides and Chlorides, compounds of fluorino or chlorine with bases, sparingly represented in Canada. And, finally, a small group of earbonaceous matters, usually classed as Organico-Chemical substances, and regarded commonly as products of alteration derived from Organic Nature. The sub-divisions of the system adopted, are shewn, by way of index, in the annexed tabular view.

I. SIMPLE SUBSTANCES :

- A. Native Non-Metallic Substances (1-2).
- B. Native Metals (3-10).
- II. ARSENIDES AND SULPHIDES:
 - Λ. Sulphides of Silver, Lead, and Zinc (11-13.)
 - В. Sulphides of Copper (14-16).
 - С. Arsenides and Sulphides of Nickel and Iron (17-22).
 - D. Sulphide of Molybdenum (23).
 - E. Sulphides of Bismuth and Antimony (24-26).

III. OXYGEN COMPOUNDS:

- A. Copper Oxides (27-28).
- B. Iron Oxides:
 - Hematite group of Iron Oxides (29-30).
 Magnetite group of Iron Oxides (31-33).
 Limonite group of Iron Oxides (34).
- С. Manganese Oxides (35-36).
- D. Uranium Oxides (37-38).
- E. Tungstenum Compounds (39).
- F. Titanium Oxides (40).
- G. Alumina and Aluminates (41-42).
- H. Silica and Silicates:
- Quartz group (43).
 Group of Basic Silicates (44-51).
 Group of Pyroxenic Silicates (52-54).

 - (3) Group of Pyroxenic Sineates (52-54).
 (4) Group of Chrysolitic Silicates (55-56.)
 (5) Group of Feldspathie Silicates (57-59.).
 (6) Group of Calcarco-Feldspathie Silicates (60-64).
 (7) Group of Nephelitic Silicates (65-66).
 (8) Group of Zeolitic Silicates (67-76).
 (9) Group of Micaccous and Chloritic Silicates (77-81.)
 (9) Group of Micaccous and Chloritic Silicates (77-81.)
 - (10) Group of Talcose Silicates (82-83).
 (11) Group of Kaolinic Silicates (84-85).
 - (12) Group of Copper and Nickel Silicates (86-87).
 - I. Curbonates:
 - Group of Auhydrous Carbonates (88-93).
 - (2) Group of Hydrous Carbonates (94-95).
- Sulphates (96–102.) K. |
- Phosphates and Arseniates (103-105.) L.
- IV. FLUORIDES AND CHLORIDES:
 - A. Fluorides (106).
 - B. Chlorides (107).
- V. BODIES OF ASSUMED ORGANIC ORIGIN:
 - A. Oxalates (108).
 - B. Carbonaceous substances (109-113).

NATIVE NON-METALLIC SUBSTANCES.

I. SIMPLE SUBSTANCES.

[This group includes the Native Non-Metallic Elements and Native Metals of Canadian occurrence. Three of these, *Graphite*,—often termed Plumbago or "Black Lead," but consisting essentially of carbon,—*Native Gold*, and *Native Silver*, are entitled to rank amongst the economic products of the country; and *Native Copper* may eventually perhaps be added to the list. The rest occur in small quantities only, or under more or less obscure conditions.]

A. NATIVE NON-METALLIC SUBSTANCES.

1. Graphite (Plumbago) :- Iron-black or dark steel-grey, with black lustrous streak, and metallic or sub-metallic aspect. Found occasionally in tabular hexagonal crystals, but more commonly in small scales, and in foliated and granular masses, which soil the hands, and leave a dark metallic trace on paper. Very sectile, and greasy or soapy to the touch. H = 1.0 - 2.0; sp. gr. 2.0 - 2.3 in pure specimens, but sometimes as high as 2.5. BB, quite infusible, and not dissolved by borax or ordinary fluxes. Consists essentially of earbon, with a variable amount of intimately intermixed siliceous or ferruginous matter, the so-called "ash." This, which becomes visible when the earbon is burnt off by long continued ignition, may vary from a mere trace to 40 or 50 per cent. The actual amount of ash scarcely affects the value of the plumbago. Samples holding 40 or more per cent. may possess as much marketable value as others in which no more than 8 or 10 per cent. is present. But a great deal depends on the composition of the ash, at least as regards certain uses. If the ash contain more than a very slight amount of lime or magnesia, the graphite is scarcely suitable for the manufacture of crucibles. A selected sample, from Buckingham, on the Ottawa, shewed the following composition :

Carbon	80.12	Siliea	12.86
		Alumina	4.33
Ash	10 80	Iron Oxide	1.07
ASII	10.00 4	Lime	0.16
		Magnesia	trace
Moisture	1.30	Loss	0.18

Another sample yielded: moisture 1.14, ash 22.06, carbon 76.80.

In the form of small scales and flaky masses, graphite is widely disseminated throughout the area occupied by the Laurentian series of which the rocks (Part V.) It occurs most commonly in the beds of crystalline view the

min lly as ons

limestone of this series; but sometimes also in the gneissoid strata, where it appears occasionally to replace the mica of these rocks. It occurs also in large flakes in some of the beds of iron ore associated with the Laurentian limestones, as at Hull, on the Ottawa. In other places, graphite forms large lenticular masses, or actual beds a foot or more in thickness, in these limestones. Occasionally also, it occurs in the form of distinct veins, traversing different strata of the Laurentian The more important localities comprise, the townships of series. Buckingham, Lochabar, Petite Nation, and Grenville, on the left bank of the Ottawa, where this useful mineral occurs in comparative abundance, and is more or less largely worked. Other localities comprise, more especially, the township of Burgess in Lanark county, and Loughborough and Bedford in Frontenac; but small quantities are met with in almost every locality in which crystalline limestone occurs. Graphite is found also in thin coatings and finely disseminated scales amongst many of the altered slates of the metamorphic region south of the St. Lawrence (See Part V.), as in Melbourne, Shipton, and elsewhere, but nowhere in workable quantities. The chief employment of graphite or plumbago is in the manufacture of drawing pencils, and refractory crucibles, the common kinds and refuse being used as a polishing material for stoves, grates, &c. It is also occasionally employed to remove friction in machinery. The present price of ordinary graphite in the New York and Boston markets varies from 7 to 10 cents (metallic currency) per lb.

2. Sulphur :--Normally, in Trimetric crystals (chiefly acute rhombic octahedrons), and in granular masses of a yellow or yellowish-grey colour. H = 2.5 or less; sp. gr. 2.0. Inflammable, burning with blue flame and sulphurous odour, and melting into brown her drops which become pale-yellow on cooling.

In Canada, sulphur occurs very sparingly in the simple set; chiet, as an efflorescent crust on specimens of decomposing pyrites from Lake Superior, and elsewhere. It is also occasionally deposited as an incrustation from springs containing sulphuretted hydrygen. In this condition, mixed with carbonate of lime, it occurs in the Township of Charlotteville, (Lot 3, Con. 12,) Norfolk County, Ontario. It is found also, here and there, as first pointed out by Dr. Bigsby, in the form of minute crystals, and in earthy coatings, on some of the lower thinbedded limestones around Niagara Falls.

B. NATIVE METALS.

3. Native Gold:—Golden-yellow; mallcable; monometric in crystallization, but occurring chiefly in small granular or leafy particles imbedded in quartz or other rock-matters, or in the form of small nuggets or fine grains mixed with sand and gravel. H = 2.0 - 3.0; sp. gr. 15.5 - 19.5 according to purity: usually about 16 to 17.5. BB, easily fusible, but not oxydizable or otherwise affected. Insoluble in nitric acid, but soluble in aqua regia.

Native gold is almost always alloyed with a certain amount of silver, by which its colour is rendered paler, and its specific gravity lowered. The average amount of silver in specimens from the Eastern Townships is about 12 p. c., or from 10 to 15 p. c. In the gold from the Hastings district, it appears to vary from about 3 to 10 p. e.; whilst in much of the gold from Nova Scotia, it does not exceed 2 or 3 per cent.

Gold occurs, in Canada, in rock formations of three distinct ages. First, in quartz veins or bands in the Laurentian Series;* more especially in the Townships of Madoc, Marmora and Elzevir, in the County of Hastings, in Ontario. Secondly in veins-mostly of quartz intermixed with ferruginous calespar or dolomite-in the more modern Metamorphic Series of the Eastern Townships of the Province of Quebec, south of the St. Lawrence (as well as in altered strata of the same general age in Nova Scotia); and thirdly, in gravel and other detrital accumulations of Post-Cainozoic age, or in part apparently of somewhat older date. These latter deposits occur chiefly at the base of the Drift-Formation (see Part V.) throughout the Eastern Townships generally. They usually yield, by washing, a considerable residuum of black ferruginous sand, with which the gold is intermixed-sometimes in nuggets weighing several ounces, but more commonly in very minute grains. The sands of most of the streams and rivers which traverse this district are, thus, more or less auriferous. The St. Francis, Chaudière, Famine, Metgermet, Du-Loup, Guillaume or Des-Plantes, and Gilbert or Touffedes-Pins, may be mentioned more especially in this connexion. A good deal of alluvial gold has been taken out of eracks and hollows in the slaty rocks forming the bed of these rivers, as at the Devil's Rapids

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^{*} The characters and relations of the various rock groups referred to in this Division, are fully described in Parts III and V. A more detailed account of the mineral voins mentioned in this Part, will also be found in Part V.

on the Chaudière, and clsewhere. The gold-bearing veins of this district have been noticed chiefly in Vaudreuil, Aubert-Gallion, and Linière, in the County of Beauce; St. Giles, in Lotbinière County; and Leeds, in Megantie (Nutbrown's location), &c. The gold is distributed very irregularly throughout the veinstone, some samples yielding upwards of \$100 per ton, and others nothing, or a mere trace (See a valuable Report by A. Michel and Dr. T. Sterry Hunt: Geological Survey of Canada, 1866). Dr. Sterry Hunt has also noticed a few minute grains of gold in a compact light-coloured rock, having apparently the composition of garnet and pyroxene, in the Township of Orford.

In the older Laurentian area of Hastings and adjoining district, in Ontario, the gold occurs only in veins or quartzose bands in gneissoid strata. Most of these bands carry auriferous mispickel and pyrites, the so-called "free gold" being comparatively rare; but in certain localities, as at the Richardson and some other mines in the immediate vicinity of Eldorado in Madoc, in the 2nd and 9th concessions of Marmora, and in parts of Elzevir, some rich shews have been obtained. Up to the present time, however, gold-mining in this region has met with but very partial success.

The presence of gold in Arsenical and Iron Pyrites, Blende, &c., will be referred to in the descriptions of these minerals. Auriferous varieties occur more especially in Hastings, and in veins on the northwest shore of Lake Superior, as well as in the Eastern Townships. Samples of Copper and Ir i Pyrites mixed with much rock-matter, from the Lake Superior region, yielded the writer amounts of gold corresponding to nearly an ounce troy in the ton of 2,000 lbs.; and some samples of crystalline mispickel from Marmora held nearly three ounces per ton.

4. Native Platinum :- <u>Tin-white</u> or greyish-white. <u>In small loose</u> grains or scales, <u>Sp. gr. 16</u> - 20. <u>Infusible</u>. <u>Insoluble in nitric</u> acid. Occurs very sparingly with native gold in the sands of the Riviere du Loup, and perhaps in some of the other iron-sands of the Eastern Townships, Province of Quebee, accompanied in places by steel-grey grains of Irid-Osmium.

5. <u>Native Silver</u> :---<u>Metallic-white</u>, but usually with dark surfacetarnish. <u>Monometric in crystallization</u>, but found <u>chiefly in small</u> granular, leafy, or filiform masses, usually imbedded in quartz or calc

NATIVE METALS.

spar. Malleable. H = 2.5 - 3.0; sp. gr. 10 - 11. BB, easily fusible, but not otherwise altered. Readily dissolved by nitric acid. A white curdy precipitate of chloride of silver, is thrown down from the solution by chlorhydric acid, or solution of any chloride, as common salt. The precipitate blackens on exposure to light, and is readily soluble in ammonia: characters which distinguish it from chloride of lead.

Native silver occurs in a broad vein of cale spar at Prince's Mine, Spar Island, and on the adjacent main land, on the north-west shore of Lake Superior. It is associated at this spot with blende, galena, amethyst, quartz, &c., and contains, according to Dr. Sterry Hunt, a small amount of gold; but the mine has been prematurely abandoned. About 20 miles to the east of this location, on the north shore of Thunder Bay, several broad veins occur, in which native silver has been found in still larger quantities. The veinstone consists in part of amethystine and colourless quartz, and partly of crystalline cale spar, accompanied by heavy spar, fluor spar, blende, galena, and pyrites. The silver is also associated here and there with silver-glance or black sulphide of silver. It does not appear to contain gold. Native silver, associated with argentiferous galena, has been still more recently discovered by Mr. Maefarlane, under very similar conditions, on an island near Thunder Cape.* This metal occurs also in the native state, but in sparing quantities, associated with copper-glance in a calespar and quartz vein on the Island of Saint Ignace; and with native copper on the Island of Michipicoten, further east. Native silver has likewise been seen occasionally, in small filaments, among the copper ores of the Acton Mine, in the Province of Quebec.

The occurrence of silver in galena, blende, pyrites, and other minerals, will be noticed under the descriptions of these substances.

6. Native Copper :- Copper-red; malleable; Monometrie in crystallization, but occurring generally in arborescent groups of minute indistinct crystals, or in masses of irregular form. II = 2.5 - 3.0; sp. gr. 8.8 - 8.95. BB, easily fusible into a shining globule which

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^{*} Assays of four large samples of veinstone from this spot, made for the Montreal Mining Company, gave the writer an average result of 7.455 per cent., corresponding to 2174 oz. 7 dwts. 11 grs. in the ton of 2000 lbs.—(*Canadian Journal*, 3rd Series, Vol. 1, p. 224.) The property has now passed into the hands of an American Company, and is being energetically worked under the management of Captain W. B. Frue.
becomes covered, on cooling, with a coating of black oxide. Readily soluble in nitric acid.

Native copper, although so abundant on the south shore of Lake Superior, has not been found, as yet, very abundantly in Canada. It occurs, however, in many of the amygdaloidal traps and greenstones, of the Upper Copper-bearing series of the north and east shores of the lake, associated with prchnite, epidote, chlorite, &c. Here and there it has been obtained in irregular masses of the weight of several pounds; but it occurs most commonly scattered through the trap in small grains which frequently present a rounded or semi-fused appearance. The principal localities comprise Battle Island and the Islands of St. Ignace and Michipicoten; also Maimanse and Cape Gargantua. According to the Report for 1863 of the Geological Survey, Native Copper occurs likewise in thin plates in red shales of the Quebec series, on the Etchemin River, below St. Henri, and at Point Levis, opposite Quebec; as well as in a kind of amygdaloidal greenstone underlying these shales at St. Flavien, in the same district. It is stated to have been found, moreover, in small dendritic and other masses, accompanying copper pyrites, apatite, and a silvery-white mica, in a quartz vein in the Township of Barford.

7. <u>Native Lead</u>:—Lead-grey; soft and malleable. BB, fuses easily, and becomes gradually volatilized, coating the charcoal with a yellow ring of lead oxide.

Native lead is of very rare occurrence. The only specimen discovered in Canada, is in the form of a thin string in colourless quartz. It was obtained by Mr. McIntyre of Fort William, Lake Superior, from the vicinity of the Kaministi quia, Thunder Bay. As the quartz contains a few scales of specular iron ore in a perfectly normal condition, it is evident that the lead cannot have arisen from the reduction of galena by the action of heat.

8. Native Bismuth: — Silver-white with reddish tinge, but usually tarnished. Sectile, but not malleable. Hemi-hexagonal in crystallization, but commonly in small masses of lamellar structure. H = 2.0— 2.5; sp. gr. about 9.7. BB, melts easily and volatilizes, coeting the charcoal with yellow oxide. Soluble in nitrie acid; the solution yields a white precipitate of bismuthic oxide on the addition of water in excess.

The only examples of Native Bismuth hitherto met with in Canada, were recognized by the writer in some rolled pieces of quartz, obtained by Mr. Herrick, from near Echo Lake, on the north-west shore of Lake Huron.

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9. <u>Native Antimony</u>:—Tin or greyish-white. Brittle. Chiefly in small masses of lamellar or fine granular structure. II = 3.0 - 3.5; sp. gr. 6.65 - 6.75. <u>BB</u>, melts and volatilizes, tinging the flame palegreen, and depositing a copious white erust on the charcoal. The only known occurrence of Native Antimony in Canada, is in the Eastern Township of South Ham (lot 27 of first range), where, mixed with antimony glance, &c., it forms several narrow veins in a clay slate of the Quebec Group.

APPENDIX TO GROUP I.

10. <u>Meteoric Iron: — Dark steel-grey; malleable; strongly magnetic;</u> H = 4.5; sp. gr. about 7.4; fracture, hackly. <u>BB</u>, infusible.

An irregular mass of malleable iron weighing about 750 lbs. was discovered in 1854, on the surface of the ground, in the Township of Madoc. Its examination by Dr. Sterry Hunt showed the presence of 6.35 per cent. of Nickel, with other characters belonging to ordinary examples of meteoric iron. It exhibits a dark coating of oxide, and contains a small amount of intermixed phosphide of iron (Schreibersite) and magnetic pyrites. Nitric acid brings out on the polished surface the so-called Widmannstüdt's figures, or intersecting lines and zigzag markings indicative of an irregular crystalline structure.

II. ARSENIDES AND SULPHIDES.

[This sub-division contains the various compounds of arsenic and sulphur with metallic bases, hitherto found in Canada. These may be conveniently described under five groups, as follows :—Sulphides of Silver, Lead, and Zine; Sulphides of Copper; Arsenides and Sulphides of Nickel and Iron; Sulphide of Molybdenum; and Sulphides of Bismuth and Antimony.]

A. SULPHIDES OF SILVER, LEAD, AND ZINC.

11. Silver Glance or Argentite: —Black, or dark lead-grey; malleable; Monometric in crystallization, but occurring commonly in small irregular masses, or in leafy or delicate arborescent forms H = 2.0-2.5; sp. gr. 7.2 - 7.4. <u>BB</u>, melts with bubbling, and yields a globule of metallic silver. 100 parts contain normally: Sulphur 12.90, Silver 87.10. Hitherto, only found with native silver, &c., at Prince's Location, Lake Superior, and in the silver veins of Thunder Bay. At the "Withers Mine," at a depth of nearly sixty feet from the surface, several crystals, combinations of cube and octahedron, measuring the fourth of an inch across, were obtained by the writer; and some others of still larger size were found in the same shaft by Mr. McIntyre of Fort William. One of these (sp. gr. 7.31) yielded : sulphur 13.37; silver 86.44; copper, slight trace. The adjacent mine of the Thunder Bay Con. pany has also furnished some good specimens.

12. <u>Galena</u>:—Lead grey; more or less <u>sectile</u>, but <u>not malleable</u>; <u>Monometric in crystallization</u>, and often <u>met with in cubes</u> (fig. 36) and in <u>combinations of the cube and octahedron</u> (fig. 37), and other

related forms : also in irregular masses, mostly with well-marked lamellar structure. Cleavage cubical and easily effected. H = 2.5; sp. gr. 7.2 - 7.7. BB, decrepitates (as a general rule) and becomes reduced to metallic lead. The



charcoal is encrusted partly with a yellow ring of lead oxide, and beyond this, with a white deposit of mixed sulphate and carbonate of lead. 100 parts of galena contain : sulphur 13.4, lead 86.6; but a minute portion of the sulphide of lead is almost invariably replaced by sulphide of silver. In most Canadian samples however, the amount of silver does not exceed ten or twelve dwts. in the ton, and is consequently insufficient to defray the cost of extraction. The known or reported exceptions to this statement are mentioned below.

Galena, as a mineral, is very widely distributed throughout Canada: both in veins, and in small crystalline masses, &c., scattered through rocks of various kinds, more especially in metamorphic and other limestones or dolomites. It is thus present in almost every mineral vein on the north shore of Lake Superior, in association with zine blende, copper and iron pyrites, &c. Also, here and there, throughout the wide Laurentian area between the northern lakes, and the Ottawa; in the limestones and dolomites of the Niagara and other formations in Ontario; in the dark calcareous shales around Quebee; in the metamorphic region of the Eastern Townships; and in the limestones of Gaspé. More special localities comprise:—Prince's Location, Lake Superior; the silver veins of Thunder Bay and Thunder Cape; many

veins holding copper pyrites, &c., north of Thunder Bay; the region around Black Bay, where it is associated with auriferous copper-pyrites in broad veins;* in well-defined veins of much promise, with gangue of highly crystalline cale-spar and heavy spar, in gneiss, in the Township of Galway, Peterborough County, and in the adjoining Township of Sommerville; in Lake, Tudor, Limerick, and Marınora, where numerous veins occur in gneissoid strata;* in the Township of Loughborough in Frontenae (the Frontenac Mine, &c.) in broad and promising veins, traversing gneiss and crystalline limestone; under similar conditions in Bedford in the same county; in Lansdowne, Leeds County; and Ramsay, in Lanark County. Galena occurs also in narrow, deceptive, gash veins (see Appendix to Part III.) in the Niagara dolomites of Mulmur (Simcoe County), Eramosa (Wellington County), and Clinton (Lincoln County).

In the Province of Quebec, this mineral occurs especially in the copper-ore veins of the Eastern Townships, as in Acton, Upton, and Ascot, and in many of the quartz veins of the Chaudière valley. Galena, apparently in workable quantities, has also been noticed by the Geological Survey at Gaspé Cove and Indian Cove, near Cape Gaspé (Report, 1863, p. 400). Argentiferous galena (properly so-called) occurs, according to Dr. Sterry Hunt, at the St. Francis Rapids on the Chaudière, associated with Arsenical Pyrites and Blende, and at Moulton Hill, near Lennoxville. The actual amount of silver appears to vary greatly, probably from intermixed particles of native silver. Three dressed samples from the Chaudière yielded respectively-32 oz., 256 oz., and 37 oz , per ton of 2240 lbs. A dressed sample from Moulton Hill yielded 65 oz. per ton. Other argentiferous varieties are reported to occur on Lake Superior (Meredith's Location, Maimanse, and elsewhere), but the silver, found in some of these, may be due to intermixed scales and filaments of native silver and silver-glance.

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^{*} A surface-sample obtained personally from a quartzose vein in the Upper Copper bearing rocks (aftered Silmian strata) of this district, gave me : 47.56 per cent, metallic lead, 8.40 per cent, metallic copper (another sample gave 11.62 per cent.), with an amount of gold equivalent to 16 dwts. 18 grs, per ton of 2000 lbs, of ore, and 2 oz. 12 dwts, of silver. The amount of gold ¹n different samples varied from 14 to 19 dwts, per ton, according to the amount of pyrites. This vein is about 10 feet wide, and carries in its centre a solid lode, at least 4 feet in width, of a mixture of copper pyrites and galena.

^{*} Some of these veins are apparently cut off, at a comparatively slight depth, by the walls coming together, and their working has been thus abandoned; but if the sinking were continued, they would probably be found to open out again.

13. Zinc Blende or Sphalerite :- Lustre, sub-metallic or resinous. Colour, brown, black, yellow, &c.; streak, mostly pale-brown. Monometric in erystallization, but occurring commonly in small irregular masses, or indistinct crystals, with well-marked lamellar structure. H = 3.5 - 4.0; sp. gr. 3.9 - 4.2. BB, infusible; but when strongly ignited with earb. soda on charcoal, it yields a white incrustation of zine oxide, which assumes a green colour when moistened with nitrate of cobalt and then subjected to ignition (see Part J, p. 35). Some of the yellow blendes emit a phosphorescent light when scratched or broken. 100 parts contain (normally) sulphur 33, zine 67; but in the dark varieties a certain amount of iron is always present, and many specimens contain a small percentage of cadmium, manganese, &c. Blende can scarcely be regarded as an ore of zine; attempts to employ it for the extraction of the metal have hitherto met with very partial success. It may be used, however, when ground to powder, as the basis of a wash or paint for wood-work or plaster.

This mineral occurs with galena in almost all the localities given in the description of that substance, but nowhere, apparently, in large quantities (see under No. 12, above). Brown and yellow varieties are scattered through all the silver-bearing veins of Thunder Bay, and some of the latter have yielded traces of gold, not exceeding, however, 2 dwts. in the ton. Small crystalline masses and grains occur also in most of the lead veins of Peterborough, Frontenac, Hastings, &c., and some of a wax-yellow colour are occasionally seen in fossil shells, or associated with gypsum in small cracks and cavities in the limestone beds around Niagara Falls, as well as in the older limestones of Kingston, Montreal, &c. Zine Blende is seen likewise in many of the veins of the Eastern Townships, as in the valley of the Chaudière, and elsewhere. An auriferous variety is stated by Dr. Sterry Hunt to accompany argentiferous galena, &c., in a quartz vein at the St. Francis Rapids on the Chaudière.

B. SULPHIDES OF COPPER.

14. Copper Glance:—Dark lead-grey, often with blue or green tarnish; streak, black and slightly shining. Crystallization Trimetric, but the crystals have mostly a pseudo-hexagonal aspect. Found commonly, however, in small granular or other masses. If 2.5 - 3.0; sp. gr. 5.5 - 5.8. BB, melts with strong bubbling or spitting, colours the edge and point of the flame green, and yields a globule of metallic copper covered by a dark scoria or crust. One hundred parts contain: Sulphur 20.2, Copper 79.8.

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This ore, often termed "vitreous copper ore" (although its lustre is perfectly metallic), occurs in small quantities in many of the mineral veins of lake Superior and Lake Huron: as on Spar Island, Pigeon River, St. Ignace, Point Porphyry, Michipicoten, Point-aux-Mines, Batchewahning Bay, Echo Lake, Bruce Mines, &c. It occurs also in many of the copper-ore veins of the Eastern Townships, as in Leeds (at the Harvey Hill and other mines), Halifax, Sutton, Brome, Shefford, Stukely, Brompton, Acton, Melbourne, Cleveland, &c. Also reported from Côteau St. Geneviève, near Quebec.

15. Purple or Variegated Pyrites (Bornite, Erubescite):—Pale brownish-red, but always presenting a rich purple or variegated tarnish; streak, greyish-black. Monometric, but rarely crystallized; mostly in irregular masses. Brittle. H = 3.0; sp. gr. 4.5 - 5.5. BB, fusible into a dark magnetic globule. Composition somewhat variable, but averaging: Sulphur 25, Copper 60, Iron 15. A sample from Lake Huron gave the author: Sulphur 24.03, Copper 63.19, Iron 11.86.

This valuable mineral (the "horse-flesh ore" of the miners) occurs in large and small masses, imbedded in, or scattered through, many of the altered strata of the Eastern Townships; and also, though less abundantly, in quartz veins traversing these strata. Some of the more important localities comprise the celebrated Acton mine in Acton Township, the Halifax mine in the township of the same name, Sweet's mine in Sutton, Cold Spring mine and Balrath mine in Melbourne, the St. Francis mine in Cleveland, and the Harvey Hill mine in Leeds; but it occurs also in other parts of these townships, as well as, more or less, throughout the entire district, associated most commonly with the ordinary or yellow pyrites, and frequently with earthy malachite, copper glance, native copper, galena, &c. The country rock is usually a dolomitic limestone, or a chloritic or micaceous slate. See further, nuder Copper Pyrites, below.

In other parts of Canada, this ore occurs but sparingly. It has been found at the Wellington and Bruce mines on Lake Huron; and in veins cutting strata of the same general age as those of the Eastern Townships, at Peint-aux-Mines, Maimanse, and elsewhere, on Lake Superior. Lake Huron specimens sometimes exhibit pseudomorphs (Dimetric tetrahedrons) after Copper Pyrites. 16. <u>Copper Furites</u> (Chalkopyrite) :-Brass-yellow, often with variegated tarnish; <u>streak</u>, <u>dark green</u>, or greenish-black. Dimetric in crystallization, but <u>commonly</u> found in irregular masses. Brittle. H = 3.5 - 4.0; <u>sp. gr. 4.1 - 4.3</u>. <u>BB</u>, melts into a dark <u>magnetic</u> globule; after roasting, yields, with carb. soda, metallic copper. One hundred parts contain : <u>Sulphur 34.9</u>, <u>Copper 34.6</u>, Iron 30.5.

This is the common ore of copper. It is familiarly known as "yellow copper ore." It occurs in small quantities, both in veins and in scattered masses, among the Laurentian strata of various localities: more especially in the townships of Lake, Madoc, Elzevir, Hungerford, &c., in the County of Hastings; North Burgess in Lanark; Escott and Bastard in Leeds, and throughout the gneissoid region generally between the Ottawa and Lake Huron. The accompanying veinstone is mostly calespar, but in some places it consists of quartz, or is of a granitic nature. Speeks of galena, blende, and iron pyrites, usually accompany the copper ore. This mineral has been found also in calespar veins traversing gneiss in Kildare, Joliette County, in the Province of Quebee. Attempts to work the ore in these Laurentian rocks have not hitherto proved successful.

In the Huroniau strata, this ore is far more abundant. Numerous veins, with quartz gangue, occur on the north shore of Lake Huron. Many of these veins carry workable quantities of copper pyrites, accompanied in most cases by small portions of variegated pyrites, and also by copper glance, iron pyrites, &c. The best known are those of the Bruce and Wellington Mines; but others occur at Copper Bay, White Fish River (the Wallace Mine), the Mississaqui, Spauish River, Garden River, Root River, Echo Lake, and elsewhere in that district. (See further, under the Huronian Formation, in Part V.)

Copper Pyrites occurs also in many localities on the east and north shores of Lake Superior, in veins traversing strata apparently of Calciferous and Chazy age (see Part V). These are known as the Copper. Bearing series of Lake Superior. Among other localities may be enumerated: Bachewahnung Bay, Maimanse, Point-aux-Mines, Mica Bay, Black River, Black Bay, Thunder Bay, and locations between Thunder Bay and Dog Lake on the Kaministiquia. Some of these veins carry but small quantities of ore, but others are exceedingly rich: those especially which occur in the vicinity of Black Bay, and in the country north of Thunder Bay. Samples from these latter districts,

NICKEL ORES.

collected personally, and others obtained by Mr. S. J. Dawson, have yielded amounts of gold varying from a few dwts. to about an oz. troy in the ton of 2000 lbs. of ore. The gangue of these veins is either quartz, or a mixture of calespar, heavy spar, amethystine quartz, and fluor spar; and the copper ore is generally accompanied by galena, zine blende, and iron pyrites.

Finally, Copper Pyrites is widely distributed throughout many of the Eastern Townships in the Province of Quebec, in strata of the same general age as those of the Copper-bearing series of Lake Superior. The copper ores of this district are shewn by Sir William Logan to occur principally in two bands of more or less magnesian rock, one at the base and the other at the summit of the middle portion, or Lauzun Formation, of these strata (see Part V). In some places, the copper is entirely in the form of yellow pyrites; in others, chiefly in the state of purple or variegated ore (No. 15, above). The more important localities of the yellow ore, on the lower band, lie in the townships of Stukely (Grand Trunk Mine, &c.), Ely (Ely Mine, &c.), Bolton (Huntington Mine, Ives Mine, &c.), Leeds (Harvey Hill Mine, &c.), Halifax (Black Lake Mine), Inverness, Tringwick, Chester, Ham, and others. On the upper band, the townships of Ascot (Ascot Mine, Belvidere Mine, Lower Canada Mine, Albert Mine, Capel or Eldorado Mine, Vietoria Mine, Marrington Mine, Griffith's Mine, Clark Mine, &e.), Sutton, Brome, Melbourne (Coldstream M., Balrath M.), and Cleveland, may be more especially enumerated.* Copper Pyrites occurs also in true veins in this district, as at the Harvey Hill and Nutbrown mines in Leeds, as well as in Inverness, and elsewhere.

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C. ARSENIDES AND SULPHIDES OF NICKEL AND IRON.

17. Arsenical Nickel Ore :—Pale copper-red, with dull greyish tarnish. Hexagonal in crystallization, but mostly in irregular masses. Brittle. H = 5.0 - 5.5; sp. gr. 6.7 - 7.3. BB, emits a strong odour of garlie, and melts into a dark globule. One hundred parts contain : Arsenic 56, Nickel 44.

The above characters are those of the ore in its normal state. In Canada, this ore, however, has only been found in admixture with other metallic compounds. A mixture of this kind, in small nodular masses

^{*} A detailed list of all the copper ore localities of the Eastern Townships will be found in the valuable Appendix of the Geological Survey Report for 1866.

associated with calespar, occurs in amygdaloidal trap on Michipicoten Island, Lake Superior. The amount of nickel according to analyses by Dr. Sterry Hunt and Prof. Whitney, varies from about 17 to 37 per cent. The colour of this variety is between tin-white and bronzeyellow; sp. gr. 7.3 - 7.4. The composition indicates a mixture of arsenide of nickel with arsenide of copper (Domeykite).

Another nickeliferous compound of a steel-grey colour, apparently a mixture of arsenide and sulphide of nickel with arsonical pyrites, occurs sparingly at the Wallace Mine, Lake Huron. It was first made known by Dr. Sterry Hunt. The surface is commonly covered, more or less, with minute hair-like crystals of nickel and iron sulphates, arising from the partial decomposition of the ore.

18. Millerite or Sulphide of Nickel:—Brass or bronze yellow. Hemi-hexagonal, the crystals mostly acicular and very minute; also found in imbedded grains and small globular masses. H = 3.0 - 3.5(but not easily ascertained); sp. gr. 4.6 - 5.6. BB, melts into a dark globule. One hundred parts contain : Sulphur 35, Nickel 65.

Occurs very sparingly, in small specks, with calespar and minute green crystals of chrome garnet, in the Township of Orford (Lot 6, Range 12), where it was first recognized by Dr. Sterry Hunt.

19. Magnetic Pyrites (Pyrhotine) : -- Bronze-yellow, with black streak. Crystal-system, Hexagonal, but crystals very rare; found commonly in granular and irregular masses. H = 3.5 - 4.5; sp. gr. 4.4 - 4.7. Slightly magnetic, many specimens exhibiting polarity. The magnetism is best shewn by bringing a specimen of some size near a suspended needle. As a general rule, a bar or horseshoe magnet will only take up very small particles. BB, emits sulphurous fumes, and melts into a dark slag-like mass. By roasting, becomes very easily converted into red oxide. Soluble in hot chlorhydric acid. One hundred parts yield, on an average, Sulphur 39.5, Iron 60.5; but many varieties contain 3 or more per cent. of nickel, replacing part of the iron. A variety from Madoc, mentioned below, yielded the writer: Sulphur 39.88, Iron 59.56, and contained no trace of cobalt, nickel, or gold.

Occurs in veins and irregular beds among the Laurentian strata north of Thunder Bay, and in other localities a short distance inland from the north shore of Lake Superior. Also, under similar conditions, near Balsam Lake, &c.; and in the Township of Madoe (Lot 18, Con.

IRON PYRITES.

2). Likewise in a calespar vein in Portneuf, Province of Quebec; and still more abundantly in St. Jerome, Terrebonne. Magnetic Pyrites occurs also in the higher metamorphic district south of the St. Lawrence, generally accompanying copper ores: as in the Townships of Barford, St. Francis, and Sutton, and at the Ives and Huntington mines in Bolton.

20. <u>Iron Purites</u> (Cubical Pyrites, Mundic, &c.) :- Pale brass-yellow -often brown on the surface from partial conversion into brown iron oxide; streak, greyish-black. <u>Monometric in crystallization</u>, and frequently found in cubes (usually with striated faces, the strize on one face running at right angles to those on the adjacent face); also in

combinations of cube and octahedron, in simple octahedrons, pentagonal dodecahedrons, &c. (Figs. 37-41.) Found still more frequently in granular, nodular, and other irregular masses. H = 6.0-6.5; sp. gr. 4.8-5.2. BB, emits sulphurous fumes, and melts in-

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to a dark magnetic globule. One hundred parts contain: <u>Sulphur</u> <u>53.3</u>, <u>Iron 46.7</u>, but a small portion of the iron is occasionally replaced by cobalt or nickel. Many varieties, also, contain traces of both gold and silver. (In this connection, it may be observed that a percentage of 0.01 is equivalent to 2 oz. 18 dwts. 8 grs. (troy) in the ton of 2000 lbs., or to 3 oz. 5 dwts. 8 grs. (troy) in the British ton of 2240 lbs.)

Iron Pyrites is of exceedingly common occurrence. It is present, more or less, in almost every mineral vein; and occurs also, in crystals, grains, and irregular masses, in rocks of all ages and of various kinds. It sometimes forms the substance of organic remains, as in examples of Trilobites, &c., from the Utica Slate of Whitby and other localities. In this condition it arises most probably from the alteration of carbonate of iron.

In the Laurentian rocks of Madoe and surrounding townships, in the copper-bearing series of Lake Superior, and in altered strata of the same general age as the latter in the Eastern Townships south of the

St. Lawrence, auriferous varieties have been noticed; but the amount of gold in these is scarcely sufficient to defray the cost of its extraction. In Elizabethtown (Lot 19, Range 2), near Brockville, and elsewhere in this vicinity, some large beds or veins of a cobaltic variety occur. Large veins occur also in Clarendon, on the Ottawa; in Terrebonne and Lanoraie; in Madoe, and throughout that district; as well as on the north shores of Lakes Huron and Superior. Extensive deposits are likewise seen in some of the Eastern Townships (Garthby, Ascot, &c.)-all of which are likely to become available at no distant day, in the manufacture of sulphuric acid. Cubical crystals of large size occur in a copper-ore vein, on Lot 8, Range 1, in Melbourne Township. Small but very symmetrical octahedrons are obtained occasionally from the thick-bedded Trenton Limestone on the Bay of Quinté, near Belleville. Cubes, pentagonal dodecahedrons, and other crystals, occur in many of the veins and gneissoid rocks of Madoe, Elzevir, Tudor, &c. Occasionally also, well crystallized examples are seen in the veins, and also in the trap dykes, of Lake Huron and Lake Superior; and small brilliant crystals occur in the white compact trachyte of Montreal. Finally, it may be mentioned, without attempting however to name all the localities of this mineral in Canada, that peculiar nodular or concretionary masses occur in the shales of the Island of Orleans, and elsewhere near Quebee; and in the more modern bituminous shales of the Portage Group, at Cape Ibberwash or Kettle Point, Lake Huron.

21. Prismatic Pyrites or Marcasite (Radiated Pyrites, Coekscomb

Pyrites, &c.) :--Light brass-yellow; Trimetric, the prismatric crystals mostly in radiated aggregations, or united in rows, as in Fig. 42. Composition and other characacters as in the common or cubical pyrites, the two minerals thus presenting an example



of Dimorphism—*i. e.*, the assumption of two distinct sets of forms by the same substance. The prismatic species is especially subject to decomposition, yielding iron vitriol.

The occurrence of prismatic pyrites in Canada was first made known by the author, who met with it in 1865 in a quartz vein (carrying copper pyrites, galena, heavy spar, &c., together with examples of cubical pyrites), in the remote Township of Neebing, a few miles east of the Kaministiquia River, on the north west shore of Lake Supe-

ARSENICAL PYRITES.

rior.* Other examples have come under his notice, on subsequent visits to this district, from some of the silver-bearing veins of Thunder Bay; and he has obtained recently a large and fine specimen from a vein in Laurentian rock in the Township of Hinchinbrook, in Frontenac County. Many of the spherical masses of pyrites with radiated structure and erystallized surface, it should be observed, though commonly referred to Marcasite, belong really to the cubical species.

22. Arsenical Pyrites or Mispickel: --Colour between silver-white and pale steel-grey, often obscured by yellowish or pale-blue tarnish; streak, greyish-black. Crystallization, Trimetric: the crystals mostly

small and short rhombic prisms, terminated by two nearly flat and striated planes (Fig. 43). Occurs also in granular and irregular masses. II = 5.0 - 6.0; sp. gr. 6.0. - 6.4. BB, emits a strong odour of garlic, and melts into a dark magnetic globule. A



garlic-like odour is also more or less perceptible when the mineral is broken by a smart blow. One hundred parts contain: Sulphur 19.6, Arsenic 46.0, Iron 34.4; but a small portion of the iron is occasionally replaced by cobalt.⁺

This mineral is useless as an ore of iron, but it serves for the production of arsenious acid, the "arsenie" or "white arsenie" of commerce, and it frequently contains minute portions of gold. In Central Canada, it occurs in the Laurentian strata of Marmora and Tudor. Specimens from Marmora, have yielded the author amounts of gold ranging from 1 oz. 3 dwts. 8 grs. to over 3 ounces in the ton of 2000 lbs.[‡] In Tudor, small crystals of mispickel § accompany Bismuth Glance. The

[‡] An amount of this kind, it will of conrese be understood, although rendering the ore of much commercial value, does not practically affect the normal composition of the mineral. One onnec per ton of 2000 lbs., for example, is equivalent only to a percentage of 0.00343.

§ Although a reference to minute crystallographic details is opposed to the plan of the present work, it may be stated, here, that these Tudor crystals present the combination shewn in the annexed Figure, in which the common brachydome $\frac{1}{2}$ is replaced by $\frac{1}{2}$ and $\frac{2}{2}$. The form $\frac{1}{2}$, the summit-angle of which equals 118° 30′, is a comparatively rare form, but it appears to be always present in the cobaltiferous varieties of Mispiekel, and in the allied species Glaucodot. The Tudor crystals, as shewn by a blowpipe examination, contain a small percentage of cobalt.

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^{*} Lot 25, Con. 5. Canadian Journal, 2nd Series, Vol. X, 408.

⁺ In this case, the roasted ore when fused with borax will impart a more or less decided blue colour to the glass. For details respecting this and other blowpipe processes and reactions see Part I.

copper-ore veins of the Huronian rocks, also shew here and there small crystals and granular masses of this mineral, as at the Bruce and Wellington Mines; and it occurs in small quantities in some of the argentiferous veins of the Upper Copper-bearing Series around Thunder Bay, Lake Superior. The altered rocks of the Eastern Townships, south of the St. Lawrence, likewise contain if in places, as near the Chaudidre Rapids in the County of Beauce, where it occurs with argentiferous galena in quartz veins; and also, according to Dr. Sterry Hunt, under similar conditions at Moulton Hill in Lennoxville. In Nova Scotia, mispickel is of exceedingly common occurrence in the gold-bearing quartz bandz, and it appears invariably to be more or less auriferous.

D. SULPHIDE OF MOLYBDENUM.

23. *Molybdenite*:—Light lead-grey, with greyish-black metallic streak. Hexagonal in crystallization, but occurring commonly in the form of small scales, or in leafy or fine granular masses. Very sectile; slightly greasy or soapy to the touch, leaving a black trace on paper, and a dull greyish-green trace on smooth porcelain. $\mathbf{H} = 1.0 - 2.0$; sp. gr. 4.4 - 4.8. BB, imparts (in the forceps) a distinct green coloration to the point of the flame, but remains infusible. In a continual blast, on charcoal, however, it deposits a white coating of molybdic acid on the support. Forms with earb. soda an alkaline sulphide (see Part I, p. 44), by which, with other characters, it may be distinguished from Graphite. One hundred parts contain : Sulphur 41, Molybdenum 59.

This mineral is at present of little commercial value.* In Canada, it occurs in small scales disseminated through many of the crystalline limestones of the Laurentian series, in the Counties of Frontenae, Hastings, Peterborough, Vietoria, &c. According to the Reports of the Geological Survey, it has been found in much larger quantity near the mouth of the River Quetachoo, in Manicougan Bay, on the north shore of the Gulf of the St. Lawrence. It occurs also in some abundance at Sea-beach Bay, near Black River, on the north shore of Lake Superior, in several veins, accompanying copper pyrites in quartz. Samples from this locality have yielded nearly 4½ per cent. of molybdenite, or about 100 lbs. per ton of ore, (Can. Jour. Vol. X, p.

^{*} As Molybdenite is quoted in chemical price-lists at from 50 cents to a dollar or more per lb., an idea is sometimes expressed that it would pay to work, if found in sufficient quantity. Inquiries, however, made in London, Paris, Humburg, Berlin, and other cities, have demonstrated the fact that a very few tons would completely overstock the market.

409). Terrace Cove is another locality in which molybdenite has been found on Lake Superior. This mineral occurs also in quartz veins at Harvey Hill, in the Township of Leeds, in small rounded masses of fine granular structure, associated with copper pyrites and crystallized dolomite.

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E. SULPHIDESOF BISMUTH AND ANTIMONY.

24. Bismuth Glance:—Light lead-grey, often with yellow or blueish tarnish; streak, black. Trimetric in crystallization, but occurring commonly in lamellar and fibrous masses. H = 2.0; sp. gr. about 6.5. BB, melts very readily into a black globule, which gradually volatilizes, with deposition of a yellow ring of oxide (and, beyond this, a greyishwhite coating of sulphate) on the charcoal. A small residuum is sometimes left: this generally shews with borax or phosphor-salt the reactions of copper and iron (see Part I.) Dissolves, with separation of sulphur, in nitric acid. The solution dropped into excess of water forms a milky or opaline liquid. Not affected by caustic potash. One hundred parts of the pure mineral contain : sulphur 18.75, bismuth 81.25.

Bismuth glance is a comparatively rare mineral. It has not hitherto been discovered, at any locality, in sufficient quantity to form a commercial ore. In Canada, it occurs in small lamellar and sub-fibrous masses in a quartz vein, with numerous interpenetrating crystals of black tourmaline, at Hill's Mine, in the rear of Tudor, one of the northern townships of the County of Hastings.

25. Antimony Glance or Grey Antimony Ore: — Light lead-grey, often with dark, or iridescent, tarnish. Trimetric in crystallization, but occurring mostly in fibrous masses. H = 2.0, sp. gr. 4.52 - 4.62. Melts per se in the flame of a candle. BB, melts rapidly, and becomes volatilized in dense white fumes, a white oxidized coating being deposited on the charcoal. The point of the flame, if directed on this, is tinged pale blueish-green. A strong solution of caustic potash converts the powdered ore into an orange-coloured compound. One hundred parts contain: sulphur 28.2, antimony 71.8.

Of rare occurrence in Canada. Hitherto, found only in small quantities, with iron pyrites and mica, in a band of crystalline dolomite, in the Township of Sheffield (Lot 28, Con. 1), in Addington County; and in small masses mixed with tremolite, under similar conditions, in Marmora. Also, in radiating fibrous masses with Native Antimony in narrow veins transversing slates of the Quebec Series, in the Eastern Township of South Ham.

Note:—A plumbiferous variety of Antimony Glance, apparently a mixture of that ore with Zinkenite or Jamesonite, has been sent to me lately from Belleville, with the intimation that it was obtained in Elzevir. It forms small fibrous or sub-fibrous masses, intimately mixed with cale-spar, and with numerous acicular crystals of Tremolite, and some massive Hornblende, in quartz. Partially soluble in caustic potash, chlorhydric acid precipitating orange-coloured flakes from the solution.

26. Red Antimony Ore (Kermesite) :—Dark cherry-red, somewhat lighter in the streak; lustre adamantine, or approaching semi-metallic. Monoclinic in crystallization, but occurring almost always in small radiating fibrous tufts, associated with Antimony Glance. H = 1.0 - 1.5, sp. gr. 4.5 - 4.6. BB, melts on the first application of the flame, and becomes rapidly volatilized. The composition is somewhat remarkable, presenting the union of a sulphur and oxygen compound. One hundred parts contain : sulphur 19.8, oxygen 4.9, antimony 75.3.

Occurs in small feathery masses, with Native Antimony and Antimony Glance, in the Eastern Township of South Ham.

III. OXYGEN COMPOUNDS.

[This sub-division comprises the various Oxides of natural occurrence, *i. e.* combinations of oxygen with various metals; and also the ternary oxygen compounds, or so-called oxygen salts, commonly regarded as combinations of an oxygen acid (silicic acid, earbonic acid, &c.) with an oxidized metallic base (lime, magnesia, alumina, iron oxides, &c.) These latter compounds form the groups of Silicates, Carbonates, Sulphates, and so forth. See the remarks on Chemical Nomenclature in Part I., and also the observations prefixed to the various groups below.]

A. COPPER OXIDES.

27. Red Copper Ore (Ruby Copper, Ruberite, Cuprite):—Red, with red streak. Normally, in Monometric crystals (chiefly the octahedron and rhombic dodecahedron) which are commonly converted on the surface into green carbonate of copper; also massive and earthy. H = 4.0 or less; sp. gr. 5.8 - 6.1. BB, imparts a green colour to

IRON OXIDES.

the flame, and becomes reduced to metallic copper. One hundred parts contain: oxygen 11.20, copper 88.80.

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In Canada, this mineral occurs in traces merely, in some of the copper ore deposits of the Eastern Townships (Halifax, Acton, &c.) Spots and stains of a more or less bright red colour, are frequently the only indications of its presence. Stains of a similar appearance, are also, and more commonly, produced, it must be remembered, by the weathering of iron ores.

28. Black Copper Ore (Melaconite): - Black, with black streak. Mostly in dull earthy masses. BB, colours the flame green, and yields metallic copper. One hundred parts of the pure mineral contain: oxygen 20.15, copper 79.85. Occurs in traces only in some of the copper ore deposits of the Eastern Townships.

B. IRON OXIDES.

[This group comprises the mineral species which consist simply of oxygen and iron; and those, of a closely related character, in which part of the iron is replaced by titanium or chromium. These species fall into three natural groups: (1) The *Hematite* group, consisting of anhydrous sesqui-oxides (or analogous compounds), Hexagonal, or rather Hemi-Hexagonal, in erystallization; (2) the *Magnetite* group, compounds (apparently) of oxides and sesqui-oxides, Monometric in erystallization; and (3), the *Limonite* group, consisting of hydrated sesqui-oxides.

(1) HEMATITE GROUP OF IRON OXIDES.

29. Hematite (Specular Iron Ore, Red Iron Ore, Red Ochre) :-This mineral occurs under several more or less distinct conditions, and especially: (1) In Hemi-hexagonal crystals, chiefly groups of modified rhombohedrons, and in lamellar and micaceous masses, with steel-grey colour, often iridescent on the surface, and with strongly marked metallic lustre (= Specular and Micaceous Iron Ore); (2) In botryoidal masses of fibrous structure, and in irregular lamellar masses, with blueish or brownish-red colour, and lustre between metallic and semimetallic (= Hematite of old authors, Red Iron Ore); and (3), In brick-red, more or less earthy and granular masses (= Reddle or Red Ochre). In these varieties, the streak or powder is equally of a red colour. H = 5.5 - 6.5 in the crystals and crystalline or semi-crystalline masses, but only 1.0 - 2.0 in the earthy and ochreous varieties. Sp. gr. 4.3 - 5.3. BB, becomes magnetic, but on charcoal remains unfused, although a very thin splinter in the forceps may be rounded at the point. One hundred parts contain, normally: oxygen 30, iron 70; but many specimens, it should be observed, are intimately mixed with quartz, chlorite slate, or other rock matter, by which the per centage of iron is much reduced.

This valuable ore occurs in Canada in strata of various periods of formation. One of its more important localities is in the Township of McNabb, in Renfrew, where it forms a bed of about 30 feet in thickness, associated with crystalline limestone of the Laurentian Series and overlaid by a magnesian limestone of Lower Silurian age. It occurs also in smaller quantities in the township of Bristol, and in Templeton and Hull, on the opposite side of the Ottawa. Other Laurentian localittes comprise, MacNab in Ronfrew; Madoc, Elzevir, Marmora, and Belmont, in Hastings and Peterborough; and Iron Island, on Lako Nipissing, where it also occurs in connection with crystalline limestone. In Huronian strata, it has been found near the Wallace Mine on Lake Huron, and still more abundantly on Lake Superior, as in the Bachewahnung District on the east shore of the lake; on the north side of Michipicoten Harbour; and in widely-extended beds in the vicinity of Pic River; mostly in green, chloritic, pyroxenic, or hornblendic slates (See Part V). In Silurian strata, hematitic or specular iron ore has been noticed in small quantities in the Potsdam Sandstone of Bastard and Ramsay; and micaccous and other varieties occur in the metamorphic strata of a somewhat higher horizon, in the Eastern Townships : as in St. Armand, Brome, and Sutton, mostly in chloritic schists, as well as in the auriferous copper-ore veins of Leeds and Halifax. Lastly, it may be mentioned, that an earthy impure variety is found in bands and small masses interstratified with the red ferrugipous shales of the Clinton or Middle Silurian Series, near Dundas, in Flamborough West.

Note :-- Small octahedrons, and other Monometric crystals, having the composition of Red Iron Ore, are occasionally found. These form the species *Martite* of some authors, but they are probably due to the alteration of Magnetic Iron Ore. See under that mineral, No. 31.

30. Titaniferous Iron Ore (Ilmenite, Menaccanite in part):--Iron-black; streak-powder, brownish-black to chocolate-brown. Hemi-Hexagonal, but commonly in lamellar and granular masses. When pure, not magnetic, but sometimes feebly-magnetic, probably from

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intermixed magnetic iron ore. H = 5-6; sp. gr. 4.3 - 5.0. BB, like Hematite; but the glass formed with phosphor-salt, after exposure to a reducing flame, has a distinctly red colour. Composition, essentially iron, titanium, and oxygen, in variable proportions. The Titaniferous ore from Baie St. Paul, on the Lower St. Lawrence, as deduced from Dr. Sterry Hunt's analysis, contains Titanium 29.63, Iron 36.11, Oxygen 29.10, in addition to 3.60 per cent. of magnesia.

This ore occurs in Canada, in vast beds or masses interstratified with feldspathic rocks of the Labrador or Upper Laurentian Series, at Baie St. Paul, below Quebec. At this locality, it exhibits a peculiar structure: an aggregation of coarse granular concretions composed of irregular lamellæ. Small grains of rutile are scattered in places through the mass. The principal bed is ninety feet in thickness and of great extent, but the ore at present is comparatively useless. This substance occurs also in grains and thin bands in a similar anorthosite or feldspathic rock (see Part III) in the neighbouring parish of Chateau Richer, and likewise under the same conditions in the Township of Rawdon, in Monteahu County. It has been detected also by the officers of the Geological Survey, amongst the iron ores of the less ancient metamorphic strata of the Eastern Townships: as in St. Francis, in Beauce County, and in Brome and Sutton.

(2) MAGNETITE CROUP OF IRON OXIDES.

51. Magnetic Iron Ore or Magnetite :--Iron-black, with black streak, and in general a sub-metallic lustre. Strongly magnetic, most specimens exhibiting polarity (see under Magnetism, Part I). Mono-

metric in crystallization, and often found in octahedrons and rhombic dodecahedrons (Figs. 45 and 46), the faces of the latter commonly striated parallel with the position of the edges of a plane of the octahedron. Occurs also still more frequently in lamellar, granular, and



FIGS, 45 and 46.

other masses, sometimes forming large beds. Also in the form of black sand. H = 5.5 - 6.5; sp. gr. 4.9 - 5.2. BB, on charcoal, infusible, but a fine splinter in the forceps may be rounded at the point. One hundred parts of the mineral contain: Oxygen 27.6, Iron 72.4 (or, oxide of iron 31.03, sesqui-oxide 68.97).

This ore, the most valuable of all the ores of iron, occurs in almost inexhaustible quantities, and of good quality, in many localities of the Laurentian area of Canada. It is usually found in the form of large beds in contact, as pointed out by Sir William Logan, with crystalline limestones of the Laurentian Series; but it occurs also interstratified with gneissoid and schistose strata of the same group, and in grains and small masses scattered through these rocks. Sometimes, likewise, it forms true veins, traversing Laurentian strata. It occurs also in beds amongst the altered Silurian rocks of the Eastern Townships; and, in the form of sand (usually mixed with Iserine), it belongs to comparatively recent deposits.

The principal or more interesting Laurentian localities lie in the following Townships :---Hull, in Ottawa County (several beds, one nearly 90 feet in thickness; the ore, here and there, mixed with layers of hematite, and also with scales of graphite); Buckingham, in the same county (in crystalline masses in broad feldspathic veins); Wentworth, Grenville, and Grandison, in Argenteuil County; Ross, in Renfrew County (in reticulating veins in cryst. limestone); South Crosby (bed of 200 feet in thickness), and Escott, in Leeds County; South Sherbrooke, in Lanark County; Bedford, in Frontenac County; Madoc, Elzevir, Marmora, in Hastings County (many large and valuable deposits, although much intermixed here and there with pyrites); Belmont, in Peterborough County (several beds of great extent), and Seymour, in Northumberland. Magnetic Iron Ore in cleavable masses, associated with Hematite, occurs also in Silurian (or Huronian) strata near the mouth of the Little Pic River, on the north shore of Lake Superior, and minute octahedrons are sometimes observable amongst the layers of hematite from this region.

The Eastern Townships of Sutton, Leeds, Bolton, Orford, &c., likewise possess deposits of magnetite, chiefly in masses and disseminated erystals, as well as in continuous bande, in dolomite, chlorite slate, serpentine, and other metamorphosed Siluran strata. Much of the ore from these localities, however, contains titanium or chromium. Lastly, in the form of black sand, alone, or mixed with Iserine, the ore occurs very commonly on the shores and islands of Lake Superior, Lake Huron, Erie, and Ontario, and on those of many of our smaller lakes. Also, here and there, on the north shore and gulf of the St. Lawrence; and mixed with the auriferous gravels of the Chaudière, St. Francis, Gilbert, and other rivers of the Eastern Townships.

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Note: --- Magnetite occasionally becomes altered by higher oxidation into *Hematite*, without change of form. The streak is then more or less red, and the magnetism scarcely perceptible. Some small octahedrons (with truncated edges) of this character, the *Martite* of some authors, were observed by the writer in a gneissoid boulder from Bass Lake, a few miles north of Orillia.

32. Iserine, or Titaniferous Magnetic Ore:-Black, with black streak, and sub-metallic lustre. More or less strongly magnetic. In minute octahedrons, sand grains, and pebbles. Other characters like those of Magnetic Iron Ore, but the glass obtained by fusion in a reducing flame with phosphor-salt has always a distinct red or redbrown colour. Composition, essentially, magnetic oxide of iron, with part of the iron replaced by titanium. A small amount of magnesia is also generally present. Forms a certain portion of most of the black magnetic sands of our lake, island, and river shores, referred to under No. 31.

33. Chromic Iron Ore :- Black or brownish-black, with, normally, a dark brown streak, and sub-metallic aspect; but the streak is often greenish or greenish-grey, from the presence of intermixed serpentine or other silicious matter. In general, slightly magnetic: if strongly magnetic, the substance is mixed with magnetic iron ore, and the streak is more or less black. Monometric in crystallization, but occurring commonly in irregular masses, mostly of granular structure. H = 5.5; sp. gr. 4.3 — 4.6. BB, like magnetite, infusible or but slightly rounded on the thin edges. With borax and phosphor-salt, a more or less pure green glass, the green colour becoming clearer and more distinct as the glass cools. Composition, theoretically, oxide of iron and sesqui-oxide of chromium, but the latter is always replaced to some extent by alumina, &c., and the iron by a certain amount of magnesia. The sesqui-oxide of chromium thus varies from about 40 to about 60 per cent., in different samples. A variety from Bolton yielded Dr. Sterry Hunt 45.90 per cent., and another from Lake Memphramagog gave 49.75 per cent.

Ocenrs abundantly in beds and seattered grains amongst the metamorphic strata (altered Silurian deposits) of the Eastern Townships and Gaspć, mostly in connection with serpentine or other magnesian rocks, the green colour of these being partly due to the presence of oxide of chromium. The principal localities comprise: Mount Albert

in the Shickshoek Range of Gaspć, and the Townships of Bolton, Ham, and Melbourne. Chromic Iron Ore, if holding about 50 per cent. of oxide of chromium, is worth in the English market about \$60 per ton of 2240 lbs. It is largely used in the preparation of chromate and bi-chromate of potash.

(3) LIMONITE GROUP OF IRON OXIDES.

34. Brown Iron Ore or Limonite (including Bog Iron Ore and Yellow Ochre) :- Brown, brownish-black, or dull-yellow ; streak, yellowish-brown or ochre-yellow. Aspect, sub-metallie in some of the dark varieties, silky and earthy in others. Occurs commonly in masses with botryoidal surface and fibrous structure, or in granular or earthy masses. $\Pi = 1.0 - 5.5$; sp. gr. 3.5 - 4.0. Heated in the bulb-tube, it gives off water, and becomes converted into red oxide. BB, turns red, and then blackens and becomes magnetic. A thin scale, in the forceps, may be rounded on the thin edges : otherwise infusible. Composition, essentially, hydrated se-qui-oxide of iron; but the amount of water varies considerably, and the more earthy varieties always contain a certain percentage of phosphoric acid, with frequently silica, alumina, oxides of manganese, and humic or other organic acids. In the submetallic and silky varieties, the average amount of metallic iron is equal to about 58 or 60 per cent.; in the average bog ores it equals about 45 or sometimes 50 per cent. : and in the ochres, it varies from about 10 to 40 per cent. The average amount of water is about 15, or from 10 to 20 per cent. Brown and Bog Iron Ores are often smelted, and the Iron Ochres are valuable as a paint material.

The varieties of this mineral hitherto found in Canada, comprise the more earthy varieties, Bog Iron Ore and Yellow Ochre. These belong to comparatively modern deposits, and, in places, indeed, they are now under process of formation. The iron is taken up by water percolating through ferruginous strata, and is held in solution for a time as bicarbonate, or in combination with organic acids; and afterwards, by absorption of oxygen, it becomes converted into insoluble sesquioxide, and is thus deposited in a hydrated condition, mixed more or less with earthy and other impurities.

In the Province of Ontario, the more important deposits of Bog Iron Ore occur in the townships of Charlotteville, Middletown and Windham, in Norfolk County, on Lake Eric; but in smaller quantities the ore occurs also in Camden Township in Kent, West Gwillimbury in

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Simcoe, Bastard in Leeds, March and Fitzroy, and also Vaudreuil, on the Ottawa, and elsewhere. Ochres occur also at the latter locality, associated with the bog ore; and extensive beds have been discovered in various places in the County of Middlesex, as well as near Owen Sound in the township of Sydenham in Grey County, and in Nottawasaga Township in Simcoe.

Bog Iron Ore, in still more valuable deposits, occurs abundantly in the Province of Quebec. The most important localities lie perhaps in the Three Rivers District, or between the rivers St. Maurice, Batiscan, and St. Anne. The old St. Maurice forges, so celebrated for their castings, were fed by the ore of this neighbourhood; and the more recently established Radnor forges, at Batiscan, draw their supply from the same district. Other deposits of bog ore occur in Lachenaie in l'Assomption County, Kildare in Joliette County, and elsewhere in that section; also in Templeton, Hull, and Eardley, on the left bank of the Ottawa. South of the St. Lawrence, the ore occurs more or less abundantly in the Eastern Townships of Stanbridge, Farnham, Simpson, Ascot, Stanstead, Ireland, &c., and in St. Lambert, St. Vallier, Villeray, Cacouna, and elsewhere. Valuable deposits of ochre occur especially near the mouth of the St. Anne, in Montmorenci, below Quebec; and at Cap de la Madeleine and Point du Lac, near the St. Maurice, in the Three Rivers District. Also in the township of Mansfield, on the Upper Ottawa. A bed of other occurs likewise in Durham, and elsewhere, in the Eastern Townships. These ochres are frequently of a dark brown or greenish-black colour, in places, from intermixture with earthy manganese ore.

C. MANGANESE OXIDES.

35. Manganite :--Steel-grey, with brownish streak, and metallic or sub-metallic lustre. Trimetric in crystallization, but occuring chiefly in fibroas masses. H = 3.5 - 4.0; sp. gr. 4.3 - 4.4. BB, infusible.s water by ignition in the bulb-tube, and forms a "turquoise enamel" with carb-soda (see Part I, p. 39). Composition, if pure: sesquioxide of manganese 89.8, water 10.2.

Said to occur in a broad vein, with quartz, cale spar, and fluor spar, traversing trap rocks, on the south shore of Bachewahnung Bay, Lake Superior.

36. Earthy Manganese Ore (Wad, Bog Manganese, Manganese Ochre) :--Black or blackish-brown, in dull, earthy, and often nodular,

masses. Very soft. BB, infusible. Yields water in the bulb-tube; and forms with carb-soda a "turquoise enamel," green whilst hot, greenish-blue and opaque when cold. Composition, essentially, hydrated oxide of manganese, but always mixed with earthy matters, and often with iron ochre. Some varieties contain baryta, others oxide of cobalt, copper, &c. The manganese is usually present both as protoxide and sesqui-oxide.

This substance occurs principally in recent deposits throughout the district south of the St. Lawrence, as, more especially, in Cleveland, Bolton, Stanstead, Tring, Aubert-Gallion, Stc. Marie (Beauce), St. Sylvester, Lauzun, &c. Deposits of this ochre have also been found on the north shore, as in Seigniorics of Ste. Anne and Cacouna, and in the immediate vicinity of Quebec. In Ontario, it has only been observed, as yet, in the Township of Madoc; and, in admixture with iron ochre, on the north east shore of Thunder Bay, Lake Superior. A sample from the latter locality, yielded the writer:

Sesquioxide of iron Sesquioxide manganese Protoxide manganese Lime	33.68 16.54 5.08 0.81	$= \{ Carbonate manganese \}$	8.23
Carbonic acidtrae Sulphurie acidtrae Phosphorie acidvery slight Water Silicious rock matter	3.78 e only t trace 3.82 36.12) (Carbonate of Thire	1.44
-			

99.83

The small amount of water in this ochre is somewhat remarkable.

D. URANIUM OXIDES.

37. Uran Ochre :---Yellow, in earthy crusts. BB, blackens, but does not fuse. Composition, probably, sesqui-oxide of uranium and water. In Canada, observed only as a coating on magnetic iron orewith intermixed actynolite, from Madoe.

38. Black Uranium Ore or Pitch-blende (Coracite, &c.):—Black, greyish-black, greenish-black, with greyish or brownish streak. Aspect between sub-metallic and vitreo-resinous. Mostly in nodular or other uncleavable masses. H = 5.5 when pure, but frequently less from intermixed earthy matters; sp. gr. 6.6 — 7.0 when pure, but sometimes as high as 8.0, and often only 4.0 or 4.5, from impurities. BB, infusible, or rounded only on the thinnest edges. Composition, normally, protoxide of uranium 32.10, sesquioxide 67.90; but, in many

TITANIUM OXIDES.

instances mixed with carbonate or silicate of lime, lead, bismuth. copper, and other compounds.

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The only known locality in which this substance occurs in Canada, is at Maimanse, on the east shore of Lake Superior. The variety found at this spot was first described by Dr. Le Conte under the name of Coracite. It is mixed with carbonate of lime and other impurities, by which its sp. gr. is reduced to between 4.3 and 4.4 (4.378 Le Conte), and its hardness to about 3.5 or 4.0. It yields also, according to the analyses of Whitney and Genth, about 5 or 6 per cent. of water (Dana's Mineralogy: 5th ed. p. 155).

E. TUNGSTENUM COMPOUNDS.

59. Wolfram :—Brownish-black, with strong, sub-metallic lustre, and blackish-brown or red-brown streak. Trimetric in crystallization, but occurring frequently in irregular masses of lamellar or columnar structure. H = 5.0 - 5.5; sp. gr. 7.1 - 7.6. BB, melts into a dull iron-grey globule with striated or crystalline surface. Consists of Tungstic acid combined with oxides of iron and manganese.

The only known examples of Canadian wolfram, were found by the writer, some years ago, in a large boulder of gneiss on the north shore of Chief's Island, Lake Couchiching. (See description in *Canadian Journal*, 2nd Series, Vol. 1, p. 308. Also, for analysis by Dr. Sterry Hunt, Vol. V., p. 303.)

F. TITANIUM OXIDES.

[See also Ilmenite and Iserine, under the Iron Ores.]

40. Rutile:—Dark-red, with peculiar adamantine lustre; streak, pale-brown or greyish. Dimetric in crystallization, the crystals often in geniculated twin-combinations. Commonly, also, in columnar and fibrous masses, and sometimes in small grains or scales (imperfect or flattened crystals). H = 6.0 - 6.5; sp. gr. 4.15 - 4.3. BB, infusible. With borax in a reducing flame, it forms a dark amethystine glass, which is transformed into a light-blue opaque enamel by exposure to an intermittent flame (see Part 1). Composition: oxygen 39, titanium 61.

Small grains or indistinct crystals of Rutile occur in the beds of Ilmenite at Baie St. Paul, below Quebec; and at other localities, in Laurentian strata, associated with this ore. Tolerably distinct crystals, half-an-inch in length, have been found in crystalline limestone on Green Island, Hog Lake, in Madoe.* Acicular crystals occur sparingly

* This locality was first pointed out by T. C. Wallbridge, of Belleville.



(716) 872-4503



in quartz cavities at the Wallace Mine, Lake Huron. Small crystalline grains and flattened crystals also, in the chloritic schists (altered Silurian strata) of some of the Eastern Townships, more especially in Sutton. Minute grains of Rutile occur also in many of the black ferruginous sands described under Nos. 31 and 32, above.

G. ALUMINA AND ALUMINATES.

[This group includes but two minerals of Canadian occurrence: Corumlum and Spinel. The first, by crystallization and atomic constitution, is related to Hematike, amongst the Iron Ores, and the second to Magnetike.]

41. <u>Corundum: Blue</u>, blueish-white, red, brownish, greenish, darkgrey; streak, white or greyish; aspect vitreous or stony. <u>Hexagonal</u>



in crystallization, but occurring frequently in grains and small granular masses. H = 9.0; sp. gr. 3.9 - 4.2. <u>BB</u>, infusible. Not dissolved by earb. soda. Consists, normally, of alumina. Transparent blue varieties form the Sapphire of

FIG. 47. FIG. 48. commerce, and red varieties, the Ruby. Coarse dull-coloured varieties are known as Adamantine Spar; and opaque, dark-grey, granular varieties (often mixed with magnetic iron ore) constitute Emery, a substance largely used as a polishing material. Some of the finer varieties of corundum exhibit, when cut especially, a peculiar opalescence, frequently in the shape of a six-rayed star. These are known as asteria sopphires, rubics, &c.

In Canada, this mineral has hitherto been noticed only in the form of blueish and pale-red grains in the crystalline Laurentian limestones of the Township of Burgess, Lanark County, Ontario. At one locality (Lot 2, Con. 9) it is associated with quartz, orthoclase, pearly-white mica, and sphene.

42. Spinel :- Red, blueish, dark-green, black; streak, white or grey; aspect, vitreous or stony. Monometric in crystallization, and

commonly occurring in octahedrons, either simple, or united in twin-forms (Figs. 49 and 50). H = 8.0; sp. gr. 3.5 - 4.5. BB, infusible. The red and transparent varieties consist essentially of alumina and magnesia (normally of alumina 72,



magnesia 28, *per cent*); in the black varieties (Pleonaste, Ceylanite), the magnesia is largely replaced, however, by oxide of iron; and in the dark green or greenish-black varieties (Gahnite, Automolite) it is almost entirely replaced by oxide of zine.

Small octahedrons and grains of a pale-blue colour (much resembling the spinel which occurs under similar conditions at Aker, in Sweden) are found in a crystalline limestone in the Seigniory of Daillebout, Jolliette County, in the Province of Quebec. Large and often very symetrical black crystals occur in crystalline limestone in Burgess, Lanark Co.; and less perfect examples of a similar color, accompanying fluor spar, apatite, and white orthoclase crystals, are found in a vein of flesh-red calcite, in the Township of Ross, in Renfrew Country, on the Ottawa.

K. SILICA AND CILICATES.

This division comprises the different varieties of Quartz and Opal, or silica in the free state; together with the natural compounds of silica with various bases, such as alumina, the iron oxides, magnesia, lime, soda, potash, an³ the like. Some of these silicates yield water when ignited; others are anhydrous in their normal condition, but frequently yield traces of water as the result of incipient decomposition. It is not possible to arrange the silicates strictly in accordance with their bases, without separating, in many instances, substances which in general characters are closely allied; and in some cases, an arrangement of this kind would lead to a separation of varieties of one and the same mineral. In the garnets, for example, certain varieties contain magnesia, and others lime or oxide of iron, &c., in place of magnesia, these bases being capable of mutual substitution without the general or essential character of the substance being altered by the change - a peculiarity known as isomorphism. The silicates possess representatives of all the crystal systems. In their hardness, they vary from 1.0 (in tale) to 8.0 (in topaz). Their aspect is most commonly vitreous, resino-vitreous, stony, or pearly, but the micas and some few other silicates (bronzite, &c.) exhibit a pseudo-metallic lustre (see Part I). The colour frequently varies greatly in examples of the same species, as it is due chiefly to minute and accidental proportions of foreign matters, or to variations in the isomorphous bodies which form the base. Thus, where protoxide of iron is largely present, the mineral will generally possess a dark-green or black colour, but where this base

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is replaced by lime or magnesia in greater or less proportion, the same mineral may be quite pale or light in colour, or even colourless. The different garnets, pyroxenes, amphiboles, tourmalines, &c., are familiar examples of this fact. The streak, however, is always white (or nearly so) under normal conditions, but it may exhibit a slight or indefinite tinge of grey, green, or brown, in a very dark or ferruginous variety, especially if the substance be slightly altered or decomposed. Many silicates unless previously ignited or fused with potash or alkaline carbonates, resist altogether the action of acids. Others become partially attacked or decomposed (some by boiling chlorhydric acid, and others by sulphuric acid), the silica separating in a granular, slimy, or gelatinous condition (See under "Action of Acids," in Part I). Some silicates, which do not gelatinize in their ordinary state, exhibit this peculiarity if previously fused or strongly ignited. Certain silicates are quite infusible in the blowpipe-flame. Others, if held, in the form of a thin or pointed splinter, in the platinum forceps (Part I), become rounded and vitrified at the point or edges; and others, again, melt into a perfect globule. In some cases, the substance exfoliates, or swells up and forms an intumescent branching mass, on the first application of the flame; and in many instances the fusion of a silicate is accompanied by continued bubbling. Silicates which contain a large proportion of silica form a clear transparent glass with carb. soda, if the latter be added little by little until the proper quantity be obtained; but phosphor-salt is a far more characteristic reagent for these bodies. When a silicate is exposed in a bead of phosphor-salt to the action of the blowpipe, the bases (lime, magnesia, alumina, &e.) become gradually taken up, whilst the silica remains wholly or in chief part undissolved. A small portion may be taken up by the hot flux, but as this cools, the silica is precipitated, rendering the glass opaline or milky. The undissolved silica, if a small fragment or scale-like particle of the mineral be subjected to the test, forms a thin, translucid, flocculent mass, technically known as a "silica skeleton," in the centre of the bead. A silicate may thus be readily distinguished from a phosphate, carbonate, sulphate, &c., as these latter bodies are rapidly and entirely dissolved (the carbonates with effervescence) by phosphor-salt under the action of the blowpipe.

The silicious minerals, hitherto discovered in Canada, are described, in this work, under twelve groups or sub-divisions; but some of these,

QUARTZ GROUP.

it should be observed, are rather groups of convenience than strictly natural collocations. Their distinctive characters are given below. The groups, themselves, comprise:—(1) Quartz group; (2) Basic Silicates; (3) Pyroxenic Silicates; (4) Chrysolitic Silicates; (5) Feldspathic Silicates; (6) Calcareo-Feldspathic Silicates; (7) Nephelitic Silicates; (8) Zeolitic Silicates; (9) Micaceous and Chloritic Silicates; (10) Talcose Silicates; (11) Kaolinic Silicates; (12) Copper and Nickel Silicates.

(1) QUARTZ GROUP.

[This group includes the different conditions of Silica in its free or uncombined state. These conditions are principally two: the crystalline anhydrous condition—yielding the different varieties of Quartz; and the uncrystalline hydrated modification, giving rise to the various Opals. Silica in the latter state, however, has not been recognized as yet in Canada.]

43. Quartz :- Colourless or variously coloured, and vitreous or stony in aspect. Streak (normally) white. Frequently found in Hexagonal crystals, consisting almost invariably of a six-sided prism, trans-

versely striated, and terminated by the planes of a six-sided pyramid. In many examples, however, the pyramidal planes, more especially, are of very unequal size, some of the faces being

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FIGS. 51 TO 53.

often abnormally developed so as to produce the partial or complete obliteration of the rest. The point of the pyramid is thus often extended into an edge, as in some of the accompanying figures. Quartz occurs also, and more frequently, in masses of irregular shape, as well as in nodular and stalactitic forms, and in small grains. Cleavage, scarcely observable: fracture conchoidal and uneven. H = 7.0; sp. gr. 2.5 - 2.8, mostly about 2.65. BB. per se. quite infusible; with carb. soda, melts with effervescence (due to the expulsion of the carbonic acid of the flux) into a transparent glass. Insoluble in the ordinary mineral acids. Consists, normally, of pure silica, the tints of the

<u>coloured varieties being due to accidental amounts of iron and manganese oxides, bituminous matter</u>, and other inessential ingredients. The principal varieties of Quartz, hitherto met with in Canada, are as follows:

(a) <u>Common Quartz</u>, <u>Rock Crystal</u>: — Vitreous or stony; mostly colourless, but sometimes pale reddish, yellowish, greenish, or grey. Forms an essential component of granite, syenite, gneiss, quartz-rock, and various other crystalline rocks, and is thus present throughout the wide area occupied by our Laurentian strata, as well as in many localities where Huronian rocks prevail, and amongst the altered strata of the Eastern Townships (See Part N). Very common also in mineral veins; as in those of Thunder Bay, Lake Superior; the Bruce Mines, Lake Huron; Harvey's Hill Mine, in Leeds; and cl-ewhere. Occasionally present likewise, in fissures and cavities in limestone rocks, as in the vicinity of Quebec, where the crystals are known as Quebee diamonds.

(b) Smoly Quartz: — In brownish crystals: Thunder Bay, Lake Superior; also near Quebec; and elsewhere.

(·) <u>Amethyst</u>:—In violet-coloured crystals, sometimes of large size. Fine specimens, associated with fluor spar, calespar, pyrites, native silver, &c., occur in veins on Thunder Bay and throughout that district; also on Spar Island, farther west, on Lake Superior. Many of these crystals present a deep reddish-brown colour on the outer surface, arising from a deposition of numerous minute spots of jasper or sesquioxide of iron. The colouring matter appears to consist in certain cases of a minute trace of some silver compound.

(d) <u>Chalcedony</u>:—In nodular semi-translucent masses of a yellowish, grey, or reddish colour. Occasionally present in the amygdaloidal traps of Lake Superior. Also in thin bands or veins, with Jasper, on the River Ouelle in Kamouraska.

(e) <u>Agate</u>:—In nodular masses of various clouded or banded colours, either feebly translucent or opaque. Very abundant in the amygdaloidal traps of St. Ignace, Agate Island, Michipicoten, &c., on the north shore of Lake Superior, and in the shingle beaches of these islands. Also in the conglomerates of Gaspé, and in the pebbly beaches along the shores of Gaspé Bay, arising from the destruction of these conglomerates.

QUARTZ GROUP.

(f) Jusper :- In opaque rounded masses, and in beds, of c brown, red, green, and other colour : sometimes striped or banded ; and always more or less dull or earthy-looking on the fractured surface. Some remarkable quartz-rocks, evidently altered couglomerates, containing pebbles of red Jasper, occur on the north-west shore of Lake Huron. Many of the dark-green and striped slates of Lake Huron, also, may be regarded as closely akin to Jasper. At Bachewahnung on the east shore of Lake Superior, bands of red Jasper are associated with hematitic iron ore; and layers and imbedded nodules occur in the copperbearing series of the north shore, as back of Thunder Bay, &c. Many of the so-called agates of this region are properly jaspers. Beds and layers of red jasper, in places very ferruginous, are found in the metamorphic strata of the Eastern Townships, as in Sherbrooke, Shipton, Broughton, &e., and on the River Onelle. Jasper peobles are associated also with agates in the conglomerates and shingle beaches of Gaspé.

(y) Chert or Hornstone :--Yellowish, brownish, reddish-white, grey, black, &c. Mostly in nodular and irregularly-shaped masses, and oceasionally in beds and veins which often present a cellular or breeciated structure. Translucent to nearly opaque. Closely allied to Chaleedony and Flint. Occurs in the form of veins traversing syenite in the township of Grenville, as first pointed out by Sir William Logan. Also in layers, &c., in the upper copper-bearing series of Thunder Bay, Lake Superior, and abundantly in imbedded nodular masses and in thin layers in the Corniferous Formation of the Devonian series of Western Canada, on the shore of Lake Erie, &c ; as well as occassionally under similar conditions in limestones of the Niagara and Trenton groups. Hornstone, or related silicious matter, forms the fossilizing substance of most of the corals and brachiopods of our Western Devonian beds, as well as that of many of the organic remains found in Silurian strata, as at Pauquette's Rapids on the Ottawa, and elsewhere.

(h) <u>Saudstones</u>; <u>Sunds</u>; <u>Gravel</u>:—Sandstones consist essentially of quartz grains, cemented together, or consolidated by pressure (see Part 111); whilst sands and gravels consist of the same substance in loose grains and pebbles. These rock matters, although occasionally colourless, usually exhibit various shades of yellow, brown, or red, from the presence of sesquioxide of iron. Sandstones are also occasionally of a green or greyish-green colour, in which case part of the

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iron is in the condition of protoxide. Some of our purest sandstones and quartz sands are found at the following localities: Pittsburg township (near Kingston): Charleston Lake, in Escott; Vaudreuil, on the Lower Ottawa; Beauharnois; the Grès Rapids, on the St. Maurice; Township of Batiscan; and also near Brockville, Perth, Owen Sound, Dundas, &c. (see Part V.)

(2) GROUP OF BASIC SILICATES.

[This group includes a small number of silicates in which the percentage of silica varies from 30 to 40. The specific gravity is comparatively high (= 3.0 to 4.75); and the hardness sufficient in all cases to scratch glass strongly (= 5.5 to 7.5, but mostly over 6.0)].

44. Zircon :- Brown, red, reddish-yellow, with resino-vitreous aspect. In Dimetric crystals, mostly square prisms, terminated at

each extremity by a four-planed pyramid (Figs. 54, 55); occasionally also in small granular masses. H = 7.5; sp. gr. 4.0 – 4.75. BB, quite infusible. Not attacked by acids. Consists of: silica 33.2, zirconia 66.8.



Occurs with plumbago, wollastonite, pyroxene, iria. 54. Fia. 55. &c., in the crystalline limestone of the Township of Grenville, in Argenteuil County. Also in granitic veins, with tourmaline, on the North River, in St. Jérôme, Terrebonne County; and, according to the Reports of the Geological Survey, in a syenitic rock, composed of red feldspar and black hornblende, on Pic Island, Lake Superior. Transparent varieties of this mineral are employed ip jewellery, under the name of Jargon or Hyacinth.

45. Andalusite (including Chiastolite):—Grey or pale-red. Occurs in rectangular and rhombic prisms, mostly of narrow diameter, and frequently in compound groupings which present the appearance of a simple prism with dark cross on the transverse

section (Fig. 56), the cross consisting of slate or other rock matter in which the prisms are imbedded. Found also in granular masses. H = 5.5 - 7.7; sp. gr. 3.1 - 3.2. BB,



quite infusible. The powder by ignition with nitrate of cobalt (p. 34) assumes a fine blue colour. General composition: silica 37, alumina 63. Occurs in somewhat indistinct crystals imbedded in argillo-mica-

ceous slates, in the immediate vicinity of intrusivo masses of granite, on Lake St. Francis, in Megantic County.

46. Tourmaline :- Of various colours-green, blue, black, brown, yellow, red. and sometimes colourless: but Canadian varieties are either black, brown, or brownish-yellow. The black variety is commonly known as Schorl, and is quite opaque. Hexagonal (or rather Hemi-Hexagonal) in crystallization, the crystals being almost invariably three-sided prisms (or these, with bevelled edges, producing a prism of nine sides). The cross fracture is thus always more or less distinctly triangular. The prisms are often longitudinally striated, and are fre-

quently much broken, especially when imbedded in quartz (Fig. 58). Tourmaline occurs also very generally in columnar, acicular, and fibrous masses. H = 6.5 - 7.0; sp. gr. 3.0 - 3.3. BB, the black and



F10. 57.

most of the brown varieties melt very easily, the other varieties being for the greater part quite infusible. Nearly all exhibit electrical properties when heated. Composition somewhat variable, but the essential components consist of: silica (averaging about 38 per cent.), boracic acid (4-9 per cent.), alumina (30-44 per cent.), with more or less sesqui-oxide of iron, magnesia, protoxide of iron, protoxide of manganese, lime (under 2 per cent.), soda, potash, and sometimes lithia. A small amount of fluorine is also generally present.

Tourmaline is of comparatively common occurrence in the Laurentian strata of Canada. It is met with both in the crystalline limestones and in many of the gneissoid or quartz beds of that formation, as well as in some of the granitic veins by which these beds are traversed. In the Ottawa district, it occurs especially in crystalline limestone, as at Calumet Falls (yellowish brown, and black, with Idocrase, &c.); in the township of Ross (brown and black, with pyroxene, &c.); in Clarendon Township, County of Pontiac; in North Burgess and Elmsley, Lanark County; in Grenville, and at Lachute, in Argenteuil County, and elsewhere. In Ross, Elmsley, Bathurst, Blythfield (near the High Falls of the Madawaska), St. Jérôme (Terrebonne County), Galway (Peterborough County), and on Yeo's Island, Stoney Lake, Charleston Lake, &c., it is found in granitic

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and sycnitic veins. Also in quartz veins and beds associated with gneissoid strata, in various part of Madoc, Tudor, Elzevir, and more or less generally throughout the back country between the Ottawa and Georgian Bay.

47. Garnet:—Variously coloured—most commonly, red, brown, black, green, or yellow: rarely colourless. Monometric in crystallization, the crystals being almost invariably either rhombic dodecahedrons or trapezohedrons (Figs. 59 and 60). Occurs also, very commonly, in

granular and lamellar masses. H = 6.5 - 7.0; sp. gr. 3.5 - 4.2. BB, most varieties melt more or less readily, the dark-red yielding a magnetic globule; but the bright-green chrome garnet and some light-coloured varieties



are infusible. After fusion or strong ignition, most varieties gelatinize in boiling chlorhydric acid (see under "Action of Acids," Part I.) Composition exceedingly variable, but essentially silica (33 to 43 per cent.), alumina or sesquioxide of iron (or both), with either lime, magnesia, protoxide of iron, or protoxide of manganese, or several of these bases combined. In the bright-green garnet (*Ouvarovite*), the sesquioxide of iron is chiefly replaced by sesquioxide of chromium, and the monoxidized portion of the base is essentially lime. All the deeplycoloured garnets are strongly ferruginous; whilst in the light-coloured varieties, iron is chiefly replaced by alumina, lime, or magnesia.

Garnets occur, in Canada, in many crystalline strata of the Laurentian series; also in the less ancient metamorphic beds of the Eastern Townships (see Part V.); and in some of the trappean rocks of Lake Superior. In Laurentian strata, they affect principally the beds of horublende-rock, and gneiss, which lie in contact with, or adjacent to, the interstratified bands of crystalline limestone, but they occur also apart from these limestones. The best-known Laurentian localities comprise: the banks of the River Rouge and adjacent country near the "Three Mountains," in the township of Clyde, Ottawa County (pink and red ferro-magnesian varieties in gneiss and quartz rock); Seignory of St. Jérôme, on the Ottawa (red, and very abundant, in gneiss); Rawdon Township, in Montealm County (in quartz-rock); Townships of Chatham, Chatham Gore, and Grenville, in Argenteuil County (red and yellowish-red varieties); Hunterstown, in Maskinonge

crystals and rounded masses in gneiss; Madoe Township (Lot 11, Con. 11, in hornblende rock with iron pyrites, &c.); Townships of Elzevir, Barrie, &c. (dark-red, in hornblende rock); Marmora (in quartz rock, &c.) It occurs thus in the Laurentian area generally between the Ottawa and Georgian Bay. In the altered strata of the Eastern Townships, yellowish-red or pale-brown garnets occur in pyroxene rock on Brompton Lake, and minute grains and crystals of bright-green chrome garnet are thickly disseminated through a 'calespar vcin at the same locality. Red garnets are found also in crystalline magnesian limestone, with tale, magnetic and chromic iron ores, &c., in the townships of Broughton and Sutton; and with black hornblende in the serpentines of Mount Albert, in Gaspé. In Orford, Dr. Sterry Hunt has discovered a peculiar variety of a white or lightcoloured calcarco-aluminous garnet, in rounded masses of somewhat waxy aspect, mixed with serpentine; and he has described the occurrence of a similar variety in more or less compact beds, holding specks of native gold, in St. Francis (Rep. 63: p. 496). Finally, it may be observed, garnets of a pale red-brown colour occur sparingly, with epidote, &c., in amygdaloidal traps, at Maimanse, on the east shore of Lake Superior.

48. Vesuvian or Idocrase: - Yellow, brown, yellowish-red, &c. Dimetric in crystallization : otherwise, both in composition and general

characters, identical with garnet. H = 6.5; sp. gr. 3.3 - 3.45. BB, more or less readily fusible. Occurs in some of the crystalline limestones of the Ottawa District : principally in brown crystals, with tourmaline, at Calamet Falls, and in the township of Clarendon; and also in small reddish-yellow crystals, with zircon, pyroxene, graphite, &c., in the township of Grenville.



49. Epidote : - Green, yellowish-green, blackish-green, grey, &c. Monoclinic in crystallization, but well-defined crystals are of rare occurrence in Canada; mostly in acicular crystals, and in columnar, reniform and more or less compact masses, or in imbedded grains. H = 6.0 - 7.0; sp. gr. 3.25 - 3.35. BB, swells up and forms a dull slag-like mass, with rounded edges. This is generally magnetic, but unlike the beads formed by hornblende, pyroxene, vesuvian, &c., it resists further fusion. After strong ignition, epidote gelatinises in

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Lauren-Eastern of Lake beds of cent to, cur also localities try near County rock); dant, in z-rock); genteuil kinonge
boiling chlorhydric acid. (See under "Action of Acids," in Part I.) General composition : silica 34 - 40, alumina 18 - 28, sesquioxide of iron 7 - 17, lime 20 - 25. This mineral is comparatively rare in the Laurentian rocks of Canada, but it occurs, although with more or less indistinct characters, in the gneissoid strata associated with the iron-ore beds of Belmont, Seymour, and Marmora; and in irregular layers in a reddish gneiss at Carleton Place, in the township of Beckwith, Lanark County, the rock, when polished, forming a handsome ornamental stone. Epidote is far more abundant in the metamorphic strata of the Eastern Townships, where it occurs mostly in rounded or irregular masses, intimately associated with quartz, and in places with mica and chlorite. It occurs thus in St. Armand, Potton, Shipton, Melbourne, and elsewhere throughout that region. Some of the best defined examples are found in spheroidal masses of a peculiar slatcrock in the seignory of St. Joseph, the epidote in these masses being associated with calcite, serpentine, chlorite, and quartz. Epidote occurs also in some of the amygdaloidal traps and greenstones of Lake Superior, as at Maimanse (with mesolite, chlorite, brown garnet, &c.), and on the Island of Michipicoten.

50. Allanite (Orthite) :- Black, brown, yellowish-brown. Monoclinic, and like Epidote in crystallization, but occurring generally in granular and amorphous masses, with strong resino-vitceous lustre. Fracture, conchoidal. H = 5.5 - 6.0; sp. gr. 3.1 - 4.2. BB, intumesces strongly, and melts into a black and usually magnetic globule. The powder is readily decomposed by hot chlorhydric acid, silica separating in a gelatinous state. General composition : silica (30 to 38 per cent.), alumina (8 to 17 per cent.), iron oxides (8 to 20 per cent.), oxide of cerium (usually about 15 or 16 per cent., but in some examples nearly 30 per cent.; generally replaced, however, in part, by oxides of lanthanum, yttrium, &c.), lime (6 to 12 per cent.), with a small amount of magnesia, and a little water, the latter indicating incipient decomposition. Allanite is of comparatively rare occurrence in Canada. Hitherto, only recognized in pitch-black masses or grains in Laurentian strata, as in the upper Laurentian feldspathic rocks around Bay St. Paul, and Lake St. John (as first made known by Dr. Sterry Hunt); and in the form of a narrow vein in gneissoid strata at Hollow Lake, the head waters of the South Muskoka. (See a notice, by the writer, in Canadian Journal, Vol. IX., p. 103).

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51. Sphene or Titunite :- Brown, yellow, greenish. Mouoclinic in crystallization (the crystals most commonly as in Fig. 62), but occurring also in small granular masses, and in veins or strings of more or less compact structure. H = 5.5; sp. gr. 3.4 - 3.6. BB, melts with bubbling into a dark glass or enamel, but sometimes on the edges only. In F10. 62. powder, decomposed by hot sulphurie acid. Consists of : silica, about about 32 per cent., titanio acid 40, lime 28, but part of the latter usually replaced by a little oxide of iron and manganese. Occurs in small dark-brown opaque crystals in the Laurentian gneissoid rocks of Tudor, Madoc, Lutterworth, Muskoka, &c. Also in crystalline limestone in Grenville, Burgess, North Elmsley, and at Lachino and Calumet Falls, in the Ottawa country. Sphene is also found in small amber-coloured grains and crystals in the grauitic trachytes of the Eastern Townships (Brome, Shefford, Yamaska), and in thin veins or strings with micaceous or slaty iron ore in the altered rocks of Sutton.

(3.) GROUP OF PYROXENIC SILICATES.

[This group consists essentially of non-aluminous silicates of lime and magnesia, these bases being partly replaced, however, in dark varieties, by protoxide of iron. Alumina is only exceptionally present, and rarely exceeds 4 or 5 per cent. Crystallization, monoclinic, or obscurely trimetric. Sp. gr. 2.9 - 3.3. Scarcely if at all attacked by acids.]

52. Amphibole (including Tremolite, Actinolite, Hornblende, &c.):-Green of various shades, greenish-white or almost colourless, brown, black. Monoclinic in crystallization, the crystals mostly rhombic or six-sided prisms, with the obtuse prism-angle (V on V in the accompa-

nying figures) = $124^{\circ} 30'$; but occurring commonly in acicular forms, and in fibrous, lamellar, and granular masses. H = 5.5 - 6.0; sp. gr. 2.9 - 3.4 (mostly 3.0 - 3.2) BB, mclts more or less easily, the dark varieties yielding a magnetic bead. Scarcely or not F10, 63.



at all attacked by acids. The greenish-white and colourless or palegrey varieties of this mineral are usually known as *Tremolite*; the bright-green, or dark-green, acicular and fibrous varieties, as *Actinolite*; and the green massive varieties, as well as those in green, brown, or black thick crystals, are commonly termed *Hornblende*, a name applied

by many authors to the species generally. A soft, silky variety, in fibrous masses, belonging, however, partly to Pyroxene (No. 53), is also known as Asbestus or Amianthus, but this variety does not appear to occur in Canada, our so-called asbestus being a fibrous serpentine, containing about 12 or 14 per cent. of water. (See under No. 83, below.) Average composition: silica (40 — 60 per cent.), magnesia (15 - 25 per cent.), lime (12 - 15 per cent.), with, in most varieties, a small amount of protoxide of iron, &c. Alumina, when present, varies in amount from less than one, to above 15 or 16 per cent., but the latter amount is only found in a few dark-coloured hornblendes of exceptional occurrence.

Amphibole is an essential constituent of many eruptive and metamorphic rocks, such as syenite, diorite or greenstone proper, syenitie gneiss, hornblende slate, &c.; and it is present accidentally in many crystalline limestones and other rocks. It occurs, thus, in various localities throughout the large area occupied by the Laurentian series of Canadian strata (see Part V), and also in the more modern metamorphic district of the Eastern Townships. Examples of Tremolite occur more especially in the crystalline (Laurentian) limestones of the Ottawa region, as at Calumet Falls, and in the townships of Algona, Blythfield, and Dalhousie. Dark-green Amphibole, in good crystals, occurs with diopside at the High Falls of the Madawaska, and elsewhere on that river. A fibrous and acicular pale-grey or greenish variety (Raphilite) is found near Perth, in Lanark County. Actinolite occurs here and there amongst the magnetic iron ores of Madoc and Belmont. Beds of hornblende rock range through Frontenac, North Hastings, &c., in the Laurentian area lying between the Ottawa and Georgian Bay; and syenitic or hornblendic gneiss occurs abundantly throughout the Laurentian area, generally. (See Parts III and V.) Black and dark green hornblende is seen in distinct crystalline masses and grains in many syenites and diorites : notably in the large development of syenite in the townships of Grenville, Chatham, and Wentworth, on the east side of the Ottawa. (See Parts III and V.) In the altered Silurian deposits, south of the St. Lawrence, green hornblende occurs in well-defined examples in the township of Potton; and actinolite is found, with talc, chlorite, fibrous or asbestiform serpentine, &c., in the townships of Brome and Sutton, as well as in beds of fibrous structure in St. Francis, Beauce County. Black hornblende,

with garnets, is associated with the scrpentines of Mount Albert, in Gaspé; and small grains and crystalline masses occur in the diorites and granitic trachytes (Part III) of Mount Johnson, Yamaska, Brome and Shefford.

53. <u>Pyroxene</u> (including Diopside, Sahlite, Augite, &c.) :- Green of various shades, greenish-white or almost colorless, brown, black.

Monoclinic in crystallization, the crystals mostly eight-sided prisms with sloping terminal planes, as in the annexed figures. The prism-faces v, v meet (over \overline{v}) at an angle of

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87° 5'; v inclines to \overline{v} at an angle of 133° 33'; $\bar{\mathbf{v}}$ and \mathbf{v}' form a right angle. Fig. 65 is the combination usually presented by the light coloured or *diopside* varieties of our Laurentian crystalline limestones. Fig. 66 represents the ordinary augite crystals of basaltic rocks: good examples occur in the trap of the Montreal Mountain. Fig. 67 represents a twin or compound crystal from Orford, presented to the writer by Dr. Sterry Hunt. It consists of two crystals of diopside, like Fig. 65, united by a front vertical face, and much extended or flattened in this direction. Pyroxene occurs also very commonly in acicular and fibrous groups, and in cleavable and also granular masses. Cleavage planes meet at angles of 87° 5' and 92° 55'. II (except in altered or abnormal varieties) = 5.5 - 6.0; sp. gr. = 3.2 - 3.5. BB, melts in general without difficulty, the dark varieties yielding in most cases a magnetic bead. Scarcely or not at all attacked by acids. In composition, essentially a bisilicate of magnesia and lime, with part of these bases replaced by protoxide of iron, de. A small amount of alumina is likewise occasionally present, as in Amphibole, the composition of these two minerals being practically identical. Pyroxene and Amphibole are also closely allied by crystallization and physical characters, but their crystals have a more or less distinct aspect, and the cleavage angles are not alike. Pyroxene exhibits also, as a general rule, a somewhat higher density, its sp. gr. varying usually from 3.25 to 5.35, whilst that of Amphibole lies most commonly between 2.9 and 3.2. Lightcoloured varieties of pyroxene are usually known as Diopside (also as Sahlite, Malacolite, Traversellite, Alalite, &c.), whilst the term Augite is generally applied to the dark varieties. (Jeffersonite, Hudsonite, Hedenbergite, Coccolite, &c., are other synonyms of this species.)

Pyroxene is of common occurrence in eruptive and metamorphic rocks (see Part III). It is especially characteristic of modern volcanic products, but occurs also in many of the more ancient trappean formations. In Canada, it is found in white and pale-green crystals in many of the Laurentian crystalline limestones, as at Calumet Falls and elsewhere in the Ottawa district. Also in large crystals, with amphibole, at the High Falls of the Madawaska; with mica, apatite, &c., in Bathurst; in well-defined crystals with pyrites in a quartz rein near Belmont Lake; in the anorthosites or Upper Laurentian strata of Château Richer; and elsewhere in these older metamorphic strata. In the more modern series south of the St. Lawrence, it occurs with garnets, &c., in Orford Township. Finally, well-defined black crystals are imbedded in the trap of the Montreal Mountain, and also in the erupted traps or dolerites of Rougemont and Montarville.

54. Hypersthene:—Brown, brownish-black, brownish-green; with pale-grey streak, and a more or less pearly-metallic lustre. Mostly in laminar or foliated masses. II = 5.0 - 6.0; sp. gr. 3.3 - 3.42. BB, gives a black magnetic bead. Essentially a silicate of magnesia and iron oxide. A specimen from Château Richer yielded Dr. Sterry Hunt: silica 51.35, alumina 3.70, protoxide of iron 20.56, lime 1.68, magnesia 22.59, volatile matter 0.10. Occurs in association with the anorthosites or feldspar rocks of the Labrador series (see Parts III and V), more especially in Château Richer, and St. Urbain, near Baie St. Paul, below Quebec.

(4) GROUP OF CHRYSOLITIC SILICATES.

[The minerals of this group are essentially silicates of magnesia, the latter base being more or less replaced, however, by protoxide of iron. Sp. gr. 3.1 - 3.5. Infusible. Gelatinizing in heated chlorhydric acid.]

55. Chrysolite or Olivine:—Yellow, green, brownish-green. Trimetric in crystallization, but rarely occurring otherwise than in small grains and granular masses imbedded mostly in eruptive rocks. H = 6 - 7; sp. gr. 3.3 - 3.5. BB, loses its colour but remains unfused, except in the case of certain highly ferruginous varieties not yet found in Canada. The powder becomes decomposed, with separation of gelatinous or floeculent silica, in both chlorhydric and sulphuric acid.

This species occurs in the trap mountains of Montreal, Rougemont, and Montarville, usually in the form of small green and yellow grains, but occasionally in indistinct crystal-masses. An analysis by Dr. Sterry Hunt yielded : silica 37.17, magnesia 39.68, protoxide of iron 22.54.

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56. Chondrodite :--Yellow, brownish-yellow. In small granular masses mostly imbedded in crystalline limestone. H = 6.0 - 6.5; sp. gr. 3.1 - 3.25. BB, infusible. Gelatinizes in acids. Consists essentially of silica, magnesia, and fluoride of magnesium; or is an oxygen compound with part of the oxygen replaced by fluorine. The latter element appears to vary in amount from about 2½ to nearly 10 per cent. Chondrodite occurs in many of our crystalline Laurentian limestones, frequently accompanied by scales of graphite. Newboro' in the township of North Crosby, in Leeds County; Grenville in Argenteuil County; and St. Jérôme in Terrebonne County, have yielded good examples.

(5) GROUP OF FELDSPATHIC SILICATES.

[This group is composed of essentially alkaline and non-magnesian silicates, containing a high per-centage of silica (62 to 69), and about 20 per cent. of alumina. H = 6 to nearly 7; sp. gr. 2.4 - 2.7. Crystallization, Monoclinic or Triclinic. Fusible in thin splinters only. Insoluble in acids.]

57. Orthoclase or Potash Feldspar:—White, red, flesh-red, applegreen, grey, &c. Lustre more or less pearly on cleavage planes, otherwise vitreous or stony. Crystallization Monoclinic, but with two wellmarked cleavage directions (parallel with base and side vertical) meeting at right angles. Crystals often compound, as in the more common twin combination shewn in Fig. 70. Found usually, however, in lamellar and granular masses. H = 6.0; sp. gr. 2.5 - 2.6. BB, fusible with difficulty, unless in the form of a thin pointed splinter, in which case the edge and point become quickly rounded. Practically, unattacked by acids. Average composition : silica 64.8, alumina 18.4, potash 16.8; but many varieties contain a small percentage of soda, replacing a portion of the potash. Orthoclase is one

of the component minerals of many crystalline rocks, granite, syenite, gneiss, &c.; it occurs also in many trappean rocks, and forms the essential component of trachytes and ordinary







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FIG. 70.

lavas. In the Laurentian strata so widely developed throughout the more northern portions of Canada (see Part V), this mineral is consequently largely present; and well defined cleavable masses, mostly of a flesh-red or greyish-white colour, may be obtained in almost every district in which gneissoid rocks occur. Some of the more remarkable Laurentian localities comprise : the townships of North Burgess, Elmsley, Grenville, Chatham, &c.; also the township of Ross, and other places in the neighbourhood of Calumet Falls; and several spots on the north shore of Lake Huron. In Burgess (Lot 3, Con. 6), among other varicties, a striped red and brownish orthoclase occurs. This presents iridescent reflections, and is the variety known as Perthite. It contains soda as well as potash. In Ross (Reufrew County) large white crystals occur with apatite and spinel in calcite veins. Green and other varieties are found in the Upper Ottawa region. Orthoclase occurs also in the more modern metamorphic strata south of the St. Lawrence, as in veins cutting altered slates in the townships of Inverness, Leeds, and Sutton; and it is likewise present in many of the eruptive rocks of this district, notably in the porphyritic trachyte of Chambly, and in the trachytes of Montreal and Brome. These varieties, according to Dr. Sterry Hunt's analyses (Report: 1863, p. 476) contain nearly equal amounts of potash and soda. Orthoclase, in common with other feldspathic silicates, yields by atmospheric decomposition, a white earthy clay, largely used, under the term of Kaolin, in the manufacture of porcelain. Workable beds of this substance have not been found, however, as yet, in Canada.

58. Albite or Soda Feldspar: —White, red, greyish-white, &c, sometimes with pale blueish or pearly opalescence. Triclinic in crystallisation, but occurring commonly in lamellar masses, readily cleavable in two directions under angles of 93° 36' and 86° 24'. One of the eleavage planes usually exhibits a delicate striation. In other respects, Albite closely resembles Orthoclase. H = 6.0; sp. gr. 2.55 - 2.65. Average composition: silica 68, alumina 20, soda (with trace of line, &c.) 12. Albite is a constituent of many trappean rocks, and it occurs a' certain granites and syenites, and in various metamorphic strata. A spalescent variety, known as *Peristerite*, occurs in the township of Bathurst (Lot 19, Con. 9), and also on the north shore of Stony Lake, in Burleigh. A white variety in cleavable masses of considerable size forms the feldspathic portion of certain granitic and gneissoid rocks of

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the more northern districts of the county of Ottawa. Fine crystals are also said to occur in a vein on Lake Massawippi (Stanstead), in the metamorphic region of the Eastern Townships.

59. Oligoclase :--White, greenish, pale-grey. Triclinic in crystallization, and closely allied in all its characters to Albite, but containing a somewhat smaller percentage of silica. The cleavage planes meet at angles of 95° 50' and 86° 10'. Occurs in Canada, according to Dr. Sterry Hunt, associated with black amphibole in the cruptive mass of Mount Johnson, in the district of Iberville, near the east shore of the River Richelieu.

(6) GROUP OF CALCAREO-FELDSPATHIC SILICATES.

[The minerals of this group are very closely related to those of the preceding division, but they are essentially lime-holding, and contain a lower per-centage of silica. They are more readily fusible, moreover; and are decomposed, or at least strongly attacked, by chlorhydric acid.]

60. Labradorite or Lime Feldspar :- Grey, greyish-white, greenishwhite, greyish-blue, with frequently a beautiful reflection of blue, green, orange, or other colour. Triclinic in crystallization, but rarely occurring otherwise than in cleavable lamellar masses, the cleavage planes, which usually present a delicate striation, meeting at angles of 93° 40' and 86° 20'. H = 6.0; sp. gr. 2.66 - 2.76. BB, in thin splinters, readily fusible. Decomposed, or strongly attacked, in powder, by ehlorhydric acid. Average composition : silica 53, alumina 30, lime 12.5, soda 4.5. This species enters into the composition of various trappean rocks, and it also forms, both alone and in admixture with other triclinic feldspars, large beds of crystalline structure associated with gneiss and other metamorphic strata. In this latter condition, it predominates amongst the Upper Laurentian or Labrador series of Canada (see Parts III and V). Fine examples occur in St. Jérôme, Morin, Abercrombie, and Mille Isles, in the County of Terrebonne, north-west of Montreal; and in boulders (probably from the above sources) scattered over Grenville township, on the lower Ottawa. The Labradorite of these localities is frequently opaque-white on the surface from semi-decomposition or weathering. A pale blue and greyish variety, without opalescence, occurs in Château Richer (Montgomery County), below Quebec. Palo greenish-blue and other opalescent examples have been obtained from boulders in the townships of Drummond and Lanark, west of the Ottawa; and a range of feldspathie

rocks, presenting fine examples of colour-reflecting Labradorite, occurs on the north shore of Lake Huron, east and south-east of French River. The occurrence of Labradorite at the latter locality was first made known by Dr. Bigsby.

61. Andesite:—This is a somewhat doubtful species apparently intermediate in character between Albite or Oligoclase, and Labradorite. A reddish feldspathic mineral in cleavable and striated masses, from the Labrador rocks of Château Richer, below Quebee, is referred to it by Dr. Sterry Hunt. Report for 1863, p. 478. Average composition: silica 59½, alumina 25¾, lime 7¾, soda 5, potash 1. Sp. gr. 2.66 — 2.67.

62. Anorchite:—This species is also very closely related to both Labradorite and Albite. It occurs in Triclinic crystals and cleavable masses of a greenish-white, reddish, pale-grey, and other colour, with H = 6 - 6.5, and sp. gr. 2.66 - 2.79. Fusible, and more or less readily decomposed by chlorhydric acid. Average composition : silica 44 - 47, alumina 30 - 35, lime 14 - 18; with small percentage of soda, potash, &c. A variety found in boulders in the vicinity of Ottawa eity was originally described under the name of Bytownite. Some of the feldspar of Château Richer, according to Dr. Sterry Hunt, belongs probably to this species. The feldspar which enters into the composition of the diorite of the Yamaska Mountain is also referred to it by the same observer; and fine crystals of anorthite, according to Mr. Thomas Macfarlane, occur in a large dyke of dioritic porphyry, of which several rocky islets in the vicinity of Thunder Cape, Lake Superior, are mainly composed.

 $**_*$ The two following species are placed for convenience in this group, as they are essentially lime-containing silicates, fusible, and decomposable in chlorhydric acid.

63. Wernerite or Scapolite: — White, grey, red, greenish, &c. Occurring in crystals of the Dimetric System (mostly combinations of a square-based prism and pyramid), and in lamellar, columnar, and sub-fibrous masses. H = 5.5 - 6.0 (under normal conditions, but often somewhat lower from incipient decomposition of the specimen); sp. gr. 2.6 — 2.8. BB, easible fusible, mostly with strong bubbling. Partially decomposed by chlorhydric acid. Average composition : silica 48, alumina 28, lime 18, soda 5, the latter sometimes largely replaced by potash. Carbonate of lime and a small percentage of water are very

113

constantly present in altered or weathered specimens. Scapolite occurs in the Laurentian limestone of Calumet Island, and in Grenville Township, on the Ottawa. Also in large crystals and eleavable masses, with sphene and augite, in the Laurentian strata of Hunterstown, Maskinonge County, Quebec; and at Golden Lake, in Algona Township, County of Renfrew. An altered or semi-decomposed variety in violetred or greyish-red cleavable masses, from the vicinity of Perth, in Lanark County, has been described under the name of *Wilsonite*.

64. Wollastonite :--White, pale-greenish, brown, grey, &c. Monoclinic in crystallization, and of the pyroxene type, but occurring commonly in thin tabular masses of fibrous structure. H = 4.5 - 5.0; sp. gr. 2.7 - 2.9. BB, more or less readily fusible. Decomposed, with separation of gelatinous silica, by chlorhydric acid. Essential composition : silica 51.7, lime 48.3. In Canada, fibrous Wollastonite occurs in many of the crystalline limestones of the Laurentian series, mixed more or less intimately with pyroxene, mica, quartz, and other minerals. Grenville Township in Argenteuil County, St. Jerome and Morin in Terrebonne, North Burgess in Lanark, and Bastard in Leeds County, are the best known localities.

(7) GROUP OF NEPHELITIC SILICATES.

[This group includes a small number of essentially auhydrous silicates of alumina and soda, in some of which chloride of sodium is also present, whilst others contain traces of chlorhydric or sulphuric acid. They fuse more or less readily, and gelatinize in acids. Canadian examples are comparatively unimportant.]

65. Nepheline, including Elwolite: — White, brownish, greenish, blueish-grey, yellowish, dull-red. Hexagonal in crystallization, but occurring commonly in cleavable masses of a more or less greasy or vitreo-resinous lustre, forming the variety known as Elwolite. H =5.5 - 6.0; sp. gr. 2.5 - 2.65. BB, easily fusible. Decomposed readily by acids, with separation of gelatinous or slimy silica. Average composition : silica 44, alumina 34, soda 17, potash 5. This species is said to occur in small orange-red granular masses in boulders with orthoclase and black amphibole, on Pic Island, Lake Superior. Also, according to Dr. Sterry Hunt, in white crystals in the granitic trachyte of Brome.

66. Sodalite :—Blue, greyish, colourless, &c. Monometric in crystallization, but occurring mostly in small granular masses. H = 5.5

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eed ery - 6.0; sp. gr. 2.15 - 2.35. BB, melts with bubbling. Gelatinizes in acids. Recognized in the form of small grains of a fine blue colour, by Dr. Sterry Hunt, in the granitic trachyte of Brome. In composition, essentially a silicate of alumina and soda, combined with 6 or 7 per cent. of chloride of sodium.

(8) GROUP OF ZEOLITIC SILICATES.

[The silicates of this group are essentially hydrous species, especially characteristic of trappean or basaltic rocks. All fuse more or less readily, the fusion in many cases being preceded by intumescence, or accompanied by bubbling, whence the old name of the group from $\zeta i \omega$ and $\lambda \partial \omega z$. Most of these minerals also gelatinize in acids, or become readily decomposed with separation of granular or slimy silica. Those which occur in Central Canada may be arranged in two subgroups, comprising (a) Culcarcous Zeolites; and (b) Alkaline Zeolites.]

SUB-GROUP A. CALCAREOUS ZEOLITES.

67. Prehuite :---Green of various shades, greenish-white. Trimetric in crystallization, but occurring mostly in botryoidal masses with crys-



talline surface and radiating fibrous structure (Fig. 71). H = 6.0 - 6.5; sp. gr. 2.8 - 2.95. BB, easily fusible with great bubbling. Attacked by boiling acids with separation of granular silica, but complete decomposition is not readily effected. In

the bulb-tube, gives off a small amount of water. Essential composition: silica 43.5, alumina 25, lime 27, water 4.5. Occurs chiefly in the trap rocks of Lake Superior, sometimes forming distinct veins, as on Slate River, an affluent of the Kaministiquia, and with imbedded nodules of native copper on an island near St. Ignace. A specimen, obtained by the author from Slate River, shewed a sp. gr. of 2.88, and yielded: silica 43.41, alumina 23.80, sesquioxide iron 1.26, sesquioxide manganese 0.53, lime 26.62, water 4.14. The "Chlorastrolite" from Isle Royale is probably a variety of Prehnite. It occurs in small nodular masses in amygdaloidal trap; or in the form of small pebbles, left by the disintegration of the trap, on the beaches of the island. Its colour is mostly dark and light green in alternate patches, and it exhibits a radiating fibrous structure and somewhat silky aspect. Sp. gr. 2.90 to 3.20, the heavier specimens invariably containing minute particles of magnetic iron ore, forming nuclei from which the fibres radiate. The amount of water varies from a little over 4.0, to about 5.5 per cent.

68. Datolite :--White or pale-green. Monoclinic in crystallization, but occurring chiefly in botryoidal masses of fibrous structure. H = 5.0 - 5.5; sp. gr. 2.95 - 3.0. BB, tinges the flame pale-green, and melts with great bubbling. In the bulb-tube yields about 5 per cent. water. Golatinizes in chlorhydric acid. Average composition : silica 38, boracic acid 21.5, lime 35.5, water 5.0. Of doubtful presence in Central Canada, but believed to occur sparingly in some of the trap rocks of Lake Superior. Abundant on the south shore of the lake, and present also on Isle Royale.

69. Laumonite:—White, greyish, pale-red, &c. Monoclinic, but mostly in fibrous groups. H = 3.5 - 4.0, but often less from ineipient decomposition of the mineral; sp. gr. 2.2 - 2.35. BB, exfoliates, and melts to a white enamel. Gives off a large amount of water in the bulb-tube. Gelatinizes in chlorhydric acid. Average composition: silica 52, alumina 21, line 12, water 15. Occurs in the amygdaloidal traps of Lake Superior, but mostly in a weathered condition.

70. Thomsonite:—White, red, &c. Trimetric, but most commonly found in indistinct acicular crystals and fibrous groups. H = 5.0 - 5.0; sp. gr. 2.3 - 2.4. BB, intumesces, and melts into a blebby glass. Gives off water in the bulb-tube. Gelatinizes in chlorhydric acid. Average composition: silica 38, alumina 30, lime 13, soda 4.5, water 13.5. Of somewhat doubtful occurrence, but some of the zeolites from the amygdaloidal traps of Lake Superior belong apparently to this species. They are mostly in a weathered and semi-decomposed condition.

71. *Heulandite*. 72. *Stilbite*. 73. *Chabazite*. These minerals are essentially hydrous silicates of alumina and lime. They are said to occur in some of our trappean rocks, but nowhere in distinct or well-characterized examples.

SUB-GROUP B : ALKALINE ZEOLITES.

74. Natrolite:—White, yellowish, &c. Trimetric in crystallization, but occurring most commonly in radiating fibrous groups. H = 5.0-5.5; sp. gr. 2.15 - 2.35. BB, tinges the flame strongly yellow, and melts very easily. In the bulb-tube, yields a large amount of water. Gelatinizes in acids. Average composition: silica 47.5, alu-

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75. Analcime: — White, greyish, pale-red, &c. Monometric in crystallization. The crystals mostly trapezohedrons, but occurring also in small granular masses. H = 5.0 - 5.5; sp. gr. 2.2 - 2.3. BB, imparts a yellow tinge to the flame, and melts without bubbling or intumescence into a more or less clear glass. In the bulb-tube, gives off water in considerable quantity. Gelatinizes in acids. Average composition: silica 54, alumina 23, soda 14, water 9. Occurs in the amygdaloidal traps of Lake Superior, and more especially, with native copper, on the Island of Michipicoten. It is said also to be present, here and there, in the trap rocks of the district around Montreal.

76. Apophyllite :---White, pale-red, &c. Dimetrie in erystallization, but occurring commonly in lamellar masses of a somewhat pearly aspect. (The crystals exhibit a pearly opalescence on the basal plane, and a vitreous lustre on the other faces.) H = 4.5; sp. gr. 2.3 - 2.4. BB, easily fusible, and yielding a large amount of water in the bulbtube. Decomposed, with separation of flocculent silica, by chlorhydric acid. Apophyllite differs from other zeolitic minerals in being nonaluminous. Average composition: silica 52, lime 25, potash 5, water 16, with a small amount of fluorine. Occurs in pale reddish and colourless foliated masses, mixed with calespar, in the silver-bearing vein of Prince's Location, on Spar Island, Lake Superior.

(9) GROUP OF MICACEOUS AND CHLORITIC SILICATES.

[The silicates of this group possess an eminently fissile or foliaceous structure, in consequence of which they admit of separation into plates or scales of extreme tenuity. Although differing more or less in composition, they form a connected series, commencing with species which consist essentially of silicates of alumina and potash, anhydrous or nearly so, and terminating in hydrated silicates of alumina and magnesia, but with intermediate species in which both potash and magnesia are present, and in which the amount of water gradually increases. Many of these intermediate links, however, have not been met with, as yet, in Canada. Through the hydrated magnesian species, there is a transition into the talcose minerals of the next group.]

77. Muscovite or Potash Mica:—Silvery-white, grey, brown, green, black, with pseudo-metallic pearly lustre. Trimetric in crystallization, the crystals usually six-sided tables or prisms with strongly-pronounced basal cleavage, but distinct crystals are comparatively rare. Most commonly in foliated or sealy masses, tough and flexible. H = 1.5 - 2.0on cleavage surface, somewhat higher on edges of folia. Sp. gr. 2.7 — 3.1. BB, whitens, and melts on the thin edges. In the bulb-tube, usually gives off a small amount of water. Not attacked by acids. Average composition: silica 46, alumina 30, sesquioxide iron 4, potash 10, water (and traces of fluorinc) 2 to 4. In some bright green varieties, 3 or 4 per cent. of oxide of chromium is present.

Muscovite is an essential compound of ordinary granite, gneiss, mica slate, and other crystalline rocks. It occurs, thus, more or less abundantly throughout the Laurentian area of Canada (Part V), and also amongst the metamorphic series of the Eastern Townships. Most commonly it forms small scaly masses, but, as cited by Sir William Logan, large crystals and plates occur in a vein of graphic granite (see Part III) on Allumette Lake, north of Pembroke in Renfrew County, and with black tourmaline on Yeo's Island, in the Upper St. Maurice. Large crystals of mica (apparently Muscovite) are also said by Dr. Bigsby to occur in granite at Cape Tourmente below Quebec. A green chromiferous variety in the form of small scales in magnesite and dolomite has been recognized by Dr. Sterry Hunt in the Eastern Townships of Sutton and Bolton.

78. Phlogopite (Magnesia Mica):—Yellowish-brown, brownish-red, olive-green, yellowish-green, blueish-grey, &c., with pearly-metallic lustre. Trimetric:—but occurring mostly in six-sided plates and broad foliated masses or in scaly particles, tough and elastic. Cleavage strongly pronounced in one direction. H = 2.0 - 2.5; sp. gr. 2.72 --2 85. BB, whitens, and generaly melts at the point and edges. In the bulb-tube, most varieties yield traces of moisture. Attacked, in powder, by hot sulphuric acid, the silica separating in fine scales. Average composition: silica 41, alumina 13 to 18, magnesia (with some oxide of iron, &c.) 30, potash (with soda) 8 to 10, water and fluorine 1 to 4.

This species occurs most generally in association with the crystalline limestones and pyroxenic beds of the Laurentian series. Large plates of economic value for stove-fronts, lanterns, &c., are obtained in the

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township of Grenville on the Ottawa, and in North and South Burgess. On the north shore of Rideau Lake in Burgess, large six-sided plates and prisms, associated with apatite and calcite, occur in great profusion. Translucent greenish-yellow prisms with calcite and diopside occur also at Calumet Falls.

Note :- Lepidolite or Lithia Mica has not yet been recognized in Canada, although abundant in Maine and in Connecticut. It is mostly in granular scaly masses of a pink, red, or greyish colour, melting easily and with much intumescence before the blowpipe, and colouring the flame earmine-red. Biotite is another magnesian mica, closely related to Phlogopite, described above, but Hexagonal in erystallization, and mostly black or dark-green in colour. It is of doubtful occurrence in Canada, but a dark-green mica from Moor's Slide on the Ottawa has been referred to this species.

79. Scybertite (Clintonite): — Brown, brownish-red. Mostly in small scaly or foliated masses with pearly-metallic aspect. H = 4.0or less; sp. gr. 3.0 - 3.1. BB, whitens but does not fuse, or melts only on the thinnest edges. Gives off water in the bulb-tube. Decomposed, in powder, by sulphuric acid. Contains a comparatively small amount of silica. Average composition: silica 20, alumina 40, iron oxide 4, magnesia 20, lime 13, water 3. Occurs sparingly in crystalline limestone with blue spinel in the seignory of Daillebout, Joliette County, Province of Quebec.

80. Chlorite (Penninite): — Dark-green, greenish-grey. Hexagonal or Hemi-Hexagonal in crystallization, but occurring principally in scaly or foliated masses, and at times in a more or less earthy condition, or in compact slaty masses. H = 2.5 or less; sp. gr. 2.6 -2.8. Sectile. Flexible in thin pieces, but not elastic. BB, generally melts upon the edges. In the bulb-tube yields water. Decomposed, in powder, by hot sulphuric acid. Average composition: silica 33, alumina 13, iron and chromium oxides 6, magnesia 35, water 13. Occurs chiefly in the altered Silurian strata south of the St. Lawrence, forming beds of chloritic slates which often carry copper ores, as in Cleveland, Bolton, Shefford, Melbourne, Ascot, and other Eastern Townships. In Sutton, St. Armand, Brome, and elsewhere in the same district, it occurs in admixture with specular iron ore, forming schistose beds or chloritic iron slates. Also in sub-foliated or more or

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less compact and sectile beds, of economic value as potstones, in Bolton and Broughton. Chlorite occurs likewise amongst some of the greenstones of Lake Huron and Lake Superior, and also forms chloritie schists at Goulais Bay on Lake Superior, Point Thessalon on Lake Huron, and elsewhere in the western lake-region. These schists are mixed in places with specular iron ore, as at the mouth of the Pie River, and at Gros Cap in Michipicoten Harbour. Both chlorite and chlorite slate occur also in association with some of the iron ores of Madoe and Marmora, in Laurentian strata.

81. Chloritoid: — Greyish-green, greenish-black, dark grey. In thin lamellar masses, and also occasionally in imbedded nodules of foliaceous texture. H = 5.5 - 6.0; sp. gr. 3.5 - 3.6. BB, in the outer flame, becomes red; in the inner flame, dark and magnetic; but resists fusion, or vitrifies only on the thinnest edges. Yields water in the bulb-tube. Decomposed by sulphurie acid. A dark greenishgrey variety from Leeds, analysed by Dr. Sterry Hunt, yielded: silica 26.30, alumina 37.10, protoxide of iron 25.92, protoxide of manganese 0.93, magnesia 3.66, water 6.10. Occurs in many of the altered schistose strata of the Eastern Townships, more especially in Brome and Leeds.

Loganite (Altered Hornblende):—This substance is derived apparently from the alteration or partial decomposition of hornblende (No. 52, above). It occurs in small dull brown crystals, resembling those of hornblende, in the crystalline limestone of Calumet Falls on the Ottawa, associated with serpentine, phlogopite, and apatite. II about 3.0; sp. gr., according to Hunt, 2.60 - 2.64. Infusible. Partially attacked by acids. Dr. Hunt's analysis shewed: silica 33.28, alumina 13.30, magnesia 25.50, iron peroxide 1.92, volatile matter (water, &c.) 16.00.

Hydrous Diallage:—This is also a product of alteration, derived apparently from augite (No. 53, above). It occurs in cleavable masses of a greenish-grey or pale green and somewhat waxy lustre, associated with apatite, caleite, and sphene, in crystalline limestone in North Elmsley, and also in association with phlogopite in North Burgess. H = 1.5 - 3.0; sp. gr. = 2.3 - 3.55. Infusible, or nearly so. Composition somewhat variable, but essentially, after Hunt's analyses: silica 36.59 - 39.70, alumina 10.80 - 14.80, magnesia 25.62 - 28.26, iron protoxide 4.32 - 9.54, water 14.0 - 17.66.

Another variety, in greenish and somewhat pearly masses with II = 5.0 and sp. gr. about 3.0, from the Eastern Township of Orford, yielded Dr. Sterry Hunt: silica 47.10, alumina 3.50, magnesia 24.58, lime 11.34, iron protoxide 8.55, water 5.5. It is related apparently to the hydrous bronzite described below.

Hydrous Bronzite: — Also an alteration-product, derived apparently from augite. Occurs in bronze-coloured cleavable and scaly masses in altered Silurian strata in the township of Ham. Dr. Hunt's analysis gives: silica 50.00, magnesia 27.17, iron protoxide 13.90, lime 3.80, water 6.30.

(10) GROUP OF TALCOSE SILICATES.

[The minerals of this group are essentially non-aluminous magnesian silicates, foliated or compact in texture, very sectile, and more or less greasy or soapy to the touch.]

82. Talc, including Steatite or Soapstone :-- Silvery or greenishwhite, pale-green, greyish: often mottled in grey and greenish tints. Hexagonal in crystallization, but occurring mostly in foliated or scaly masses, the folia flexible but not elastic (Talc), or in beds of a subgranular, slaty, or compact texture (Steatile or Soapstone). Very sectile, and more or less soapy to the touch. H = 1.0 - 2.0; sp. gr. 2.56 -2.8. BB, sometimes exfoliates, but melts only on the thinnest edges. In the bulb-tube, yields a little water. Scarcely attacked by acids. Average composition : silica 63, magnesia 33, water 4; but some specimens contain merely a trace of water, whilst others yield 6 or 7 per cent. Talc appears to be of rare occurrence in the more ancient metamorphic rocks of Canada, but a bed of grey and dark greyish-green steatite, mixed with magnesian carbonate of lime, occurs near the village of Bridgewater in Elzevir, County of Hastings. It is also said to have been found in Galway or Somerville. In the higher metamorphic strata (altered Silurian deposits) south of the St. Lawrence, talcose slates, on the other hand, are not uncommon, and beds of steatite are comparatively abundant. These lie principally in the townships of Bolton, Sutton, Potton, Stanstead, Leeds, and Vaudreuil. As shewn by Dr. Sterry Hunt, they frequently contain traces of oxide of nickel. A bed of mottled and pale-green steatite of excellent quality, has been found recently by Mr. Peter McKellar near Thunder Bay, on Lake Superior. A specimen analysed by the writer, yielded : silica 62.67, magnesis 33.40, oxide of iron 0.86, water 1.88. The more compact kinds of steatite are capable of economic employment in the manufacture of fire-bricks, stoves, baths, gas-burners, culinery vessels, table ornaments, &c., and other varieties are used as a paint material. Powdered talc or steatite appears also to be occasionally added to ordinary lead paint with a view to produce increased lustre; and it has been employed to lessen friction in machinery. .

Pyrallolite or Renselacrite:—This substance agrees essentially in composition and general characters with steatite, but presents the cleavage and occasionally the crystalline form of augite. It is evidently a product of alteration. Mostly greenish-white, pale-green, grey, or brownish, with somewhat waxy lustre. Very sectile. H = 2.5 - 3.0; sp. gr. 2.6 - 2.8. Infusible, or fuses only on the thinnest edges, but differs (although perhaps only in some examples) from steatite, proper, in being partially attacked by hot sulphuric acid. Occurs in beds in the crystalline limestone of Grenville on the Ottawa. Also in the townships of Ramsay, Rawdon, and Lansdowne. The Grenville variety yielded Dr. Sterry Hunt: silica 61.60, magnesia 31.06, iron protoxide 1.53, water 5.60.

83. Serpentine (including Retinalite, Chrysotile, &c.) :--Greyisl. green, oil-green, greyish-yellow, brown, reddish, sometimes nearly white, and often veined or mottled. Mostly in compact, granular, or slaty masses, forming rock-beds. Occasionally fibrous, and then commonly known as Serpentine-asbestus or Chrysotile. Also at times in pseudomorphous crystals derived from the alteration of chrysolite, pyroxene, amphibole, spinel, and other species. H = 2.5 - 5.0, but in general about 3.0. Very sectile. Sp. gr. 2.2 (fibrous varieties) to 2.66; usually about 2.5. BB, infusible, or fusible on the thin edges only. In the bulb-tube yields water. Decomposed by heated acids, especially by sulphuric acid. Average composition : silica 42, magnesia 42, iron protoxide 3, water 13. In Canada, serpentine is met with abundantly in the older crystalline or Laurentian rocks, and still more extensively in the altered Silurian strata of the Eastern Townships and Gaspé. In Laurentian rocks it occurs principally in connection with the crystalline or Eozoon limestones, as, more especially in the township of Grenville on the Ottawa, on Calumet Island, and in the township of Burgess in Lanark County. These Laurentian scrpentines are mostly pale-green or yellowish, often with spots and streaks of a reddish-brown colour. Scrpentine occurs also, in smaller quantities, in some of the iron-ore beds of Belmont and Marmora. In the more modern metamorphic strata south of the St. Lawrence, large beds, mostly intermixed with carbonate of lime or dolomite, and thus forming scrpentine marbles of more or less beauty, occur in the townships of Melbourne, Orford, Broughton, Boulton, Ham, and Garthby, and abundantly around Mount Albert in Gaspé. In many of these localities, the serpentine is closely associated with chromic iron ore. In St. Francis in Beauce County. serpentine occurs also in connection with magnetic and titaniferous iron ore, and in Roxton, Brompton,

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Orford, and other townships of that district, it often carries copper pyrites and other copper ores. Finally, a fibrous asbestiform variety is found in Melbourne, Bolton, and Ham. Many of these scrpentine beds will evidently become of much economic value at no distant day.

Aphrodite:—White, yellowish-white. In soft, earthy, or waxy-looking massesstrongly adherent to the tongue. Essentially a hydrated silicate of magnesia, allied to serpentine and also to meerschaum. Occurs in small quantities, in a bed of steatite or pyrallolite (see under No. 62 above) in the township of Grenville on the Ottawa.

[(11) GROUP OF KAOLINIC SILICATES.

[The minerals of this group much resemble in aspect and general characters the tales and steatites of the preceding group. Foliated examples present a pearly lustre and taleose appearance, and compact and granular varieties are more or less soapy to the touch and adherent to the tongue. These Kaolinic silicates, however, differ from the taleose species in being essentially non-magnesian. They are hydrated silicates of alumina, or of alumina and potash, and are evidently products of alteration, derived from the decomposition of feldspathic and other aluminous silicates. As, with all substances of this kind, composition and physical characters are necessarily somewhat variable, numerous so-called species might be made out of these products if slight points of difference were taken into consideration; but Canadian examples may be referred to two or three types, as given below.]

84. Kaolinite or Pholerite: — Pearly-white, pale-green, greenishgrey, and sometimes red from admixture with scaly red iron ore. Occurs in soft unctuous scaly masses, and also in a more or less compact and granular condition. Very sectile, and soapy to the touch. H = 1.0 - 2.0: sp. gr. 2.33 - 2.63. BB, sometimes exfoliates or expands in bulk, but remains unfused. In the bulb-tube, yields a large amount of water. The light-coloured varieties assume a fine blue colour after ignition with nitrate of cobalt (see Operation 3, under the Application of the Blowpipe, in Part I). Scarcely attacked by acids. Average composition: silica 46, alumina 40, water 14. Occurs in fissures of a sandstone of the Quebee group near Chaudière Falls (Dr. Sterry Hunt); also, accorning to Dr. Hunt, in films in the joints of some of the quartzose sandstones of the Huronian series. A red ferruginous variety in strongly soiling particles which become lustrous when rubbed, occurs in Madoc and elsewhere in the counties of Hastings

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and Peterborough, and probably in other parts of that region. Finally, it may be observed that many of the metamorphic slates of the Eastern Townships appear to owe their nacreous talcose aspect to the presence of kaolinite, or to that of the related non-magnesian silicates described under Pinite, below.

85. Pinite (including Aluminous Agalmatolite and Parophile, &c.): — Greenish or greyish-white, dull-yellow, grey, green, brown, &c. In compact, granular, and sometimes slaty masses: also occasianally in pseudomorphous crystals. Very sectile, and more or less unctuous to the touch. H = 2.5 to 3.5; sp. gr. 2.65 - 2.8. BB, infusible, or fusible with difficulty on the edges only. The light coloured varieties assume a blue tint after ignition with nitrate of cobalt. In the bulb-tube, yields water. More or less attacked by acids. Average composition: silica 45 to 55, alumina 25 to 35, iron oxides 1 to 4, potash 6 to 10, with small amounts of magnesia, soda, &c., and from 5 to 8 per cent. of water.

The term Pinite (from the Pini mine near Schneeberg in Saxony) was originally restricted to certain brown pseudomorphous crystals apparently derived from the decomposition of Iolite, but it is now applied by Dana so as to include a number of related substances of various colours and modes of occurrence. These substances are essentially hydrated silicates of alumina and potash, much resembling the magnesian steatites and serpentines in their physical characters. One of the best known is the Chinese Agalmatolite or Figure-stone, but many of the so-called agalmatolites are magnesian in composition, and identical with steatite. Dr. Hunt refers the Wilsonite (see No. 63, above) to this group, on account of its composition; but its physical characters are quite distinct from those of the typical pinites and agalmatolites. It wants the sectility and soapy feel, for example, so characteristic of these latter, whilst it possesses, on the other hand, a distinctly spathoid structure.

The agalmatolite variety occurs in beds and layers amongst the more or less altered Silurian strata of the Eastern Townships of Canada, especially in St. Nicholas (Lévis), where it forms green and greenishwhite layers in an indurated elay-slate of the Quebee group (see Part V); St. Francis (Beauce), also in elay-slate, in yellow, waxy-looking, semi-translucent layers; and on Lake Memphramagog in Stanstead, where it occurs in yellowish beds, one of which presents a sub-fibrous

silky aspect, in chloritic slate. Analyses of these varieties by Dr. Sterry Hunt, will be found in the elaborate Report of the Geological Survey for 1863.

Glauconite (Green Sand):—This substance occurs only in the form of small grains and specks of a green colour, distributed through sandstone and other rocks. These grains appear to consist essentially of a hydrated silicate of alumina, potash, and iron oxide. They occur in a sandstone of the Quebec group near Poiet Lévis, and on the Island of Orleans. Certain bright-green markings in the siliceous Black River limestones of Lake St. John, in Rama. have also been referred to Glauconite.

(12) GROUP OF COPPER AND NICKEL SILICATES,

[The minerals of this group, as regards Canadian examples, are comparatively unimportant. They are essentially hydrated silicates of amorphous or earthy structure: products of decomposition of copper and nickel ores.]

86. Chrysocolla : — Green, greenish-blue, occasionally passing into brown and black. In amorphous masses, and in earthy crusts on copper ores, frequently mixed with malachite. II = 1.5 - 4.9; sp. gr. 2.1 -2.3. BB, blackens, and imparts a green colour to the flame-border, but does not fuse. In the bulb-tube yields a large amount of water. Attacked and decomposed by heated acids. Average composition : silica 34, oxide of copper 45, water 21. The brown and black varieties are intermixed with iron and manganese oxides, or with black oxide of copper. In Canada, found sparingly amongst some of the copper ores of Lake Superior.

87. Genthite (Nickel-Gymnite) :--Pale-green, greenish-yellow. Occurs in earthy crusts, and in amorphous masses sometimes with botryoidal surface. H = 1.5 - 4.0; sp. gr. 2.2 - 2.5. BB, blackens, but remains infusible. In the bulb-tube gives off a large amount of water. A soft earthy variety from Michipicoten yielded Dr. Sterry Hunt: siliea 35.80, oxide of nickel 32.40, water 12.20; but in another specimen (less thoroughly dried before analysis) the amount of water was found equal to 17.10 per cent. Hitherto only recognized in Canada in a vein on the Island of Michipicoten, Lake Superior. The vein traverses amygdaloidal trap, and carries small grains and rounded masses of native copper and native silver.

I. CARBONATES,

[This sub-division comprises the natural compounds of Carbonic Acid with various bases, such as lime, magnesia, and the like. In acids

CARBONATES.

these compounds become decomposed with strong effervescence, the latter effect being due to the liberation of their carbonic acid, but in many cases the application of heat is required to develope the phenomenon. The substance, in the form of a small particle or two, or in powder, may be conveniently examined, with some diluted chlorhydric acid, in a test-tube or deep watch-glass supported over a common spiritlamp. (See under "Action of Acids," in Part I.) The carbonates, also, when fused with borax before the blowpipe, dissolve with marked effervescence, their carbonic acid being driven off. Up to the present time, only eight carbonates have been recognized amongst Canadian minerals, and five of these are altogether unimportant. We arrange the whole, therefore, simply under two groups : Anhydrous and Hydrous Carbonates, respectively]

(1) GROUP OF ANHYDROUS CARBONATES.

[The anhydrous earbonates belong properly to several distinct groups: more especially to a *Rhombohedral Group*, typified by calcite or ordinary cale spar, and including dolomite, magnesite, siderite, &c.; and a *Prismatic Group* of Trimetric and Monoclinic species, typified by Arragonite, and including earbonates of lead, baryta, strontia, &c. But in Canada, the latter group is only represented, and that obscurely, by arragonite or prismatic earbonate of lime.]

88. <u>Calcite or Calc Spar</u> (Rhombohedral Carbonate of Lime) :--White, grey, reddish-white, greenish-white, yellowish-white, red, black, &c., but mostly colourless or lightly tinted. <u>Hexagonal or Hemi-</u><u>Hexagonal in crystallization</u>, with strongly pronounced <u>rhombohedral</u> <u>cleavage</u>. The crystals are chiefly obtuse and acute rhombohedrons (figs. 72 and 74); combinations of a rhombohedron and hexagonal prism, the so-called "nail-headed" crystals (fig. 73); and more or less acute scalenohe-

drons (fig. 75), the mineral in the latter form being often popularly known as "dog-tooth spar." Caleite

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spar." Calcite Fig. 72. Fig. 73. Fig. 74. Fig. 75. occurs also abundantly in lamellar, columnar, fibrous, granular, and earthy masses. The crystals and crystalline masses break readily into

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rhombohedrons which measure 105° 5' over a polar edge, and 74° 55' over other edges. In some of its conditions, this species presents a more or less pearly or silky lustre; and all transparent specimens exhibit in certain directions a strongly-marked double refraction, as in the so-called "Iceland Spar." This is best shown by placing a rhom. boliedron, as obtained by cleavage, with its broader faces over a ruled line or other thin object, and turning the crystal so as to make it revolve around this. In the direction of a line joining the obtuse plane angles of the rhombic face, the two images coalesce; but in the opposite direction they are more or less widely separated, according to the thickness of the crystal. H = 3.0 in crystals and cleavable masses, but less in earthy varieties. Sp. gr. = 2.5 - 2.75, mostly. about 2.7. BB, infusible, but glows strongly and becomes caustic, the carbonic acid being expelled. Readily soluble with strong effervescence in diluted acids, without the aid of heat. Normal composition : carbonic acid 44, lime 56, but a small portion of the lime is very generally replaced by magnesia, protoxide of iron, protoxide of manganese, &c.

The varieties presented by this mineral are comparatively numerous. Those which occur in Canada may be arranged under three divisions, comprising: (a) Crystals, and crystalline cleavable varieties; (b) Concretionary and stalactitic varieties; (c) Rock varieties.

(a) Crystallized and cleavable varieties of Calvite: --- Rhombohedrons and scalenohedrons of calcite occur in many of the mineral veins on the north shore of Lake Superior; at the Bruce and Wellington Mines, Lake Huron; in the galena-bearing lodes of Galway, Ramsey, Loughborough, &c.; and in some of the copper lodes of the Eastern Townships. In a "pocket" or "vug" in the Shuniah vein north of Thunder Bay, the writer observed a large bunch of scalenohedral crystals, many of which measured upwards of 18 inches in length. Some large scalenohedrons have also been observed at the Wellington Mines on Lake Huron. Fine cleavable and transparent masses of calcite occur at Harrison's Location on the Island of St. Ignace, Lake Superior; and others, perfectly fit for optical purposes, were found in abundance in the upper part of the main shaft at the Galway lead mine in North Peterborough. Crystallized examples occur likewise in hollows and in fissures of many of our Silurian and Devonian strata, as more especially, in the Trenton limestone near Lachine, and in the same formation in the township of Huntingdon in

CARBONATES.

Hastings County; in dolomitic beds of the Quebee group near Point Levis, opposite Quebee; and, in the Niagara formation, in the vicinity of the Great Falls, Hamilton, Dandas, and elsewhere. Many of the amygdaloidal trap rocks of Lake Superior and Lake Huron, also, enclose nodular cleavable masses of calcite, and occasionally the more open amygdaloidal cavities are lined with crystals. These are almost always scalenohedrons, or combinations in which one or more scalenohedrons predominate.

(b) Concretionary and Stalactitic varieties of Calcite: — These varieties are being constantly formed by deposition of carbonate of lime from springs and streams in limestone districts, and from water percolating through limestone rocks. Carbonate of lime, consisting of equal atoms or combining weights of carbonic acid, is comparatively insoluble in water, but the bicarbonate, containing two parts of carbonic acid to one of lime, dissolves to a certain extent. Water contains very generally a small amount of free carbonic acid, derived from the atmosphere, decaying organic matters, &c., and thus it is enabled to take up a certain quantity of carbonate of lime, this becoming converted into bicarbonate. The latter compound, however, is extremely unstable. It parts with carbonic acid very readily, even by simple exposure to the air. The insoluble carbonate thus again results, and is necessarily precipitated from the water, the precipitation often taking place upon moss, roots, and other organic bodies, converting these into so-called

"petrifactions." Water issuing from limestone strata often deposits concretionary masses of carbonate of lime, in this manner, as at Hamilton, Rockwood, the Falls of Noisy River, the banks of Beaver River in Euphrasia and Artemisia, and



other places along the escarpment of the Niagara Formation (see Part V). Deposits of this kind are commonly known as *Calcareous Tufa*. Specimens from Hamilton, more especially, are hard and solid, and admit of a good polish. They are mostly of a brownish-yellow colour. Caverns and hollows of greater or less extent often occur in limestone rocks. Water percolating into these through minute fissures in tho roof, very generally deposits on the latter a thin coating of carbonate of lime, and then dropping on the floor, deposits there a further portion

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of calcareous matter. In this manner, the process constantly going on, stalactites and stalagmites originate, the two occasionally meeting in the form of a pillar. These stalactitic deposits usually exhibit a radiated fibrous structure, with frequently a botryoidal surface. Some large stalactites have been obtained from a cavern at the lower falls of the Nottawa River in Mono (Geological Report, 1863, p. 334); and others, of smaller size and less symmetrical form, have been found in adjoining townships.

(c) Rock Varieties :—These come properly under review in Parts III and V of this work. They comprise the various kinds of limestone, including Crystalline Limestone, the finer varieties of which are commonly known as Marble; Ordinary Limestone; Lithographie Limestone; Oolitic Limestone, composed of minute spherical concretions; Earthy Limestone or Chalk, and so forth. In Ganada, valuable beds of marble occur in the Laurentian strata of McNabb, Grenville, Wentworth, Bastard, Marmora, Elzevir, &c.; and in the more recent metamorphic series south of the St. Lawrence, in St. Armand, St. Joseph, Melbourne, Orford, Dudswell, and elsewhere, many of the marbles from these localities being mixed with green and other coloured serpentine. In some of the unaltered Lower Silurian strata, also, red, grey, black, and brown marbles occur: as at St. Lin, Caughnawaga, St. Dominique, Montreal, Cornwall, Point Claire, and Pakenham. Sce further, under Part V.

89. Arragonite (Prismatic Carbonate of Lime) :--Colourless and of various colours, yellow, blueish, brownish-red, &e. Trimetrie in crystallization, and often in compound crystals which sometimes present a pseudo-hexagonal aspect. Also in fibrous and stalactitic masses. II = 3.5 - 4.0; sp. gr. 2.9 - 2.95. BB, infusible, but becomes opaque and falls into powder. Soluble in acids with strong effervescence. Composition identical with that of calcite, carbonate of lime being thus a dimorphous body—*i. e.*, a substance capable of assuming two distinct sets of physical characters. Fibrous arragonite appears to occur sparingly amongst the Lake Superior traps; and occasionally in stalactitic coatings on the sides of cracks in some of our limestone rocks, as in the township of Tring and elsewhere, but no very distinct or crystallized examples have as yet been found.

90. Dolomite (Pearl Spar, Bitter Spar) :-- White, grey, brownish, &c. Crystallization Hemi-Hexagonal, the crystals being, mostly, obtuse

CARBONATES.

rhombohedrons, the faces of which are often more or less eurved. Occurs also in lamellar cleavable masses, with cleavage angles of $106^{\circ} 15'$ and $73^{\circ} 45'$, and in granular and rock masses. H = 3.5 -4.0; sp. gr. 2.8 - 2.95. BB, infusible, but becomes caustic. Slowly soluble in cold acids, but rapidly dissolved with strong effervescence if the acid be gently heated. Essential composition : carbonic acid, lime, and magnesia, forming carbonate of lime 54.35, carbonate of magnesia 45.65, but small portions of the lime and magnesia are very generally replaced by protoxido of iron and protoxide of magnese, by which the cleavage angle is slightly altered. The various rhombohedral carbonates, Calcite, Dolomite, Magnesite, Siderite, Rhodochro, site, &c., merge, in fact, into each other by intermediate transitional types, to some of which distinct names have been given. The ferruginous and manganesian dolomites become brown by weathering.

Crystals and erystalline varieties of dolomite occur in many of the metalliferous veins of Lake Superior and Lake Huron, and occasionally in those of the Eastern Townships and other parts of Canada. Groups of small rhombohedrons of more or less pearly aspect, have been obtained, more especially, from the Wellington Mines on Lake Huron. Small rhombohedral erystals occur also in cavities and on the sides of cracks, &c., in many limestone strata : as in the dolomitic limestones of the Calciferous Formation near Preseott on the St. Lawrence, and Rigaud on the Othwa; and also in the dolomitic beds of the Niagara Formation in the vicinity of the Falls, and elsewhere.

In the form of rock-masses, dolomite is of very common occurrence in many parts of Canada A white fine-granular crystalline variety, or dolomite marble, occurs in Laurentian strata at Lake Mazinaw in the township of Barrie, Frontenac County; and many of the marbles from the altered strata of the Eastern Townships are more or less magnesian or dolomitic. In the unaltered Silurian series, beds of dolomite, of a more or less sub-crystalline texture, make up the strata of the Guelph Formation, as seen in the townships of Elora, Guelph, Dumfries-Waterloo, Bentinck, &c.; and dolomitic limestones, or mixtures of limestone and dolomite, belong to various other formations of this series, more especially to the Calciferous, Chazy, Niagara, and Ouondaga groups, as described fully under these divisions in Part V.

91. Magnesite :--- White, brownish, &c. Hemi-Hexagonal in crystallization, the crystals mostly obtuse rhombohedrons; but occurring

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commonly in cleavable masses (with cleavage angles = $107^{\circ} 29'$ and $72^{\circ} 31'$), and in granular and rock varieties. If (in pure varieties) = 3.5 - 4.5; sp. gr. 2.8 - 3.0, or slightly higher in the brown ferruginous varieties. BB, infusible. Soluble in heated acids with effervescence. Normal composition: carbonic acid 52.4, magnesia 47.6, but part of the magnesia usually replaced by protoxides of iron and manganese. In Canada, this mineral occurs only in rock masses, forming beds in the altered Silurian strata of the Eastern Townships of Sutton and Bolton, south of the St. Lawrence, where it is associated chiefly with serpentine and steatite.

92. Rhodochrosite, or Carbonate of Manganese :-- This species has not yet been found in Canada in distinct examples, but it occurs in admixture with many of the manganese ochres (No. 96), and is also present, in traces, in some of the altered strata of the Eastern Townships. Colour, rose-red or pale-red, weathering brown.

93 Siderite or Spathic Iron Ore (Spherosiderite, Cluy Iron Ore, &c. :-Yellowish, greyish, light and dark brown, green, &c, Occurs under several conditions, and more especially: (1), in rhombohedrons, scalenohedrons, and lamellar masses, with cleavage-angles of 107° and 73° (Spathic Iron, proper); (2), in spherical or concretionary masses with radiating fibrous structure in trappean rocks (Spherosiderite); and (3), in nodular masses and occasionally in layers, mostly of a brown colour and earthy or dull stone-like aspect (Clay Iron Ore). Crystalline varieties of this mineral have not yet been recognized with certainty in Canada; but nodules and thin layers of clay ironstone or clay iron ore occur in the Devonian strata of Gaspé, associated with a small seam of impure coal, and with fossilized plant-remains (see Part V). This variety is a mixture of carbonate of iron (more or less converted into brown iron ore) with argillaceous matter. Although rarely yielding more than 25 or 30 per cent. of iron, clay ironstone, as occurring in the Carboniferous strata of Europe and the United States, supplies a large number of furnaces, and yields metal of good quality. The nodules have usually a strongly-marked slaty structure; and, when broken, they almost invariably exhibit the impression of a fern frond, fish skeleton, or other organic body. Small fragments after ignition before the blowpipe, or in a glass tube held over a common spirit lamp, assume at first a red colour, and then become black and magnetic.

CARBONATES-SULPHATES.

(2) GROUP OF HYDROUS CARBONATES.

[This group is only represented in Canada by the two cuprcous carbonates Malachite and Azurite, and these species do not occur in well characterized examples, but merely as incrustations on Copper Ores, or in the form of stains and small earthy masses in copper-holding rocks.]

94. Malachite or Green Carbonate of Copper:-Green of various shades, with pale-green streak. Monoclinic in crystallization, but crystals exceedingly rare. Mostly in botryoidal masses of concentric lamellar, and fibrous structure; in earthy coatings on copper ores; and in the form of streaks and markings in copper-holding rocks. H = 3.5-4.0 (in the solid state); sp. gr. 3.7 - 4.0. BB, tanges the flame green, and becomes rapidly reduced to metallic copper. Soluble in acids with effervescence. Essential composition: carbonic acid 20, oxide of copper 72, water 8. Occurs in small quantities with copper glance, native silver, &c., in a cale-spar vein on Spar Island, Lake Superior, and in small earthy incrustations and markings amongst many of the copper ores and associated veinstones of Lake Superior and Lake Huron generally. Also under similar conditions in Madoc, Marmora, and various other localities in which copper pyrites occurs in larger or smaller quantities; and especially in the chloritic and other altered rocks of the metamorphic country south of the St. Lawrence, as in the townships of Leeds, Halifax, Inverness, Ham, Shipton, Cleveland, Stukely, Bolton, Brome, Sutton, &c.

95. Azurite or Blue Carbonate of Copper :— This species has hitherto been recognized only in small incrustations and stains of a blue colour, associated with malachite, at most of the localities named under No. 94, above. The blue carbonate contains : carbonic acid 25.6, oxide of copper 69.2, water 5.2.

K. SULPHATES.

[The mineral substances placed under this division may be regarded, according to the commonly received view, as compounds of sulphurie acid with one or more oxydized bases, such as baryta, lime, oxide of ead, alumina, and the like. As regards physical characters, these bodies exhibit a non-metallic aspect, and either a colourless or a very faintly-coloured streak, the colour in the latter case being green or blue, or occasionally yellow. They afford representatives of all the systems of crystallization; Trimetric and Monoclinic types being especially abundant H = 1.0 - 40. The sulphates may be easily distin-

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guished from carbonates, phosphates, silicates, &c., by fusion in a reducing flame on charcoal with carb-soda; or better with a mixture of carb-soda and a little borax, as the latter reagent facilitates the decomposition of earthy sulphates, and prevents the absorption of the fused mass. An alkaline sulphide is formed by this treatment. When moistened, and placed on a piece of silver or on lead test-paper (a bright coin or glazed visiting eard may be used as a substitute), the fused mass produces a black or brown stain (of sulphide of silver or sulphide of lead). The stain may be easily removed from the silver, by friction with moist bone-ash.

Amongst the sulphates generally, several natural groups stand out with great prominence. The Trimetric group of anhydrous species, for example, containing the Sulphates of Baryta, Strontia, Lime, Lead, &c.; the Gypsum group; the Monometric group of Alums; the Prismatic groups of Vitriols; and others of subordinate importance. The sulphates hitherto found in Canada, are too few, however, to admit of distribution into special groups of this kind. In the descriptions which follow, the anhydrous species Barytine and Celestine are placed first. To these, succeeds the hydrous sulphate, Gypsum; and a few sapid types of obscure or comparatively rare occurrence, close the list.]

96. Barytine or Heavy Spar:—White, yellow, reddish, pale-blue, grey, &c. Crystallization Trimetric (Figs. 77-78, and other combinations). Occurs very commonly in lamellar masses and aggregations of large flat crystals with cleavage angles of $101^{\circ} 40'$, 78° 20', and 90°, yielding a right rhombic prism. Also in masses of a granular or more or less compact structure. H = 3.0 - 3.5; sp. gr. 4.3 - 4.7, mostly about 4.4 - 4.5. BB, generally decrepitates strongly, tinges the flame-border pale-green, and melts into a white enamel. Dissolves entirely in carb.-soda before the blowpipe. Not attacked by acids.

Normal composition : sulphuric acid 34.33, baryta 65.67. This mineral occurs abundantly in many parts of Canada. In the Laurentian strata,



it occurs in veins *per se*, and as a gangue or veinstone with galena, more especially in the townships of Lansdowne in Leeds County; Bathurst and North Burgess in Lanark County; McNab, Renfrew County; Dummer and Galway, in Peterborough County; and Som-

SULPHATES.

merville in Victoria County. Red crystals were discovered by Mr. Murray on Iron Island, Lake Nipissing; and other examples have been met with in the copper-ore veins of Lake Huron. Isolated pale reddish-yellow crystals (Fig. 78) were found by the writer (Canadian Journal, November, 1865) in veins in Neebing Township near Fort William, Thunder Bay, Lake Superior, and subsequently in other mineral veins in that region. Massivo and sub-crystalline varieties form also large veins near Pigeon River west of Fort William; and other veins of a similar character are said to occur east of Thunder Cape, as at Edward Island in Black Bay, and elsewhere. Heavy Spar has also been noticed in some of the scrpentines and other altered strata of the Eastern metamorphic region south of the St. Lawrence, as on the Bras River, where a white variety occurs in small veins. Nodular masses of a red or reddish-yellow colour occur with fibrous and granular gypsum in the Hudson River strata of Cape Rich ou Georgian Bay; and small crystals and crystalline masses are occasionally found in cavities of the dolomitic limestones of the Caleiferous and Niagara groups, as near Brockville, and in the vicinity of Niagara Falls. Heavy Spar is employed in the manufacture of paints, and is too frequently used in this connection as a fraudulent substitute for white lead. It is also the chief source of the baryta salts of the laboratory.

97. Celestine :- White, blue, grey, &c. Trimetric in crystallization, the crystals frequently bearing a close resemblance to those of heavy spar. Occurring also in lamellar and crystalline masses, with cleavage angles of about 104°, 76°, and 90°, yielding a right rhombic prism; and in masses of fibrous or granular structure. H = 3.0 - 3.5; sp. gr. 3.95 - 3.97. BB, imparts a crimson colour to the point and border of the flame, and melts into a white alkaline enamel. Dissolves entirely, by fusion, in carb. soda. Not attacked by acids. Normal composition: sulphuric acid 43.6, strontia 56.4. This mineral occurs chiefly in sedimentary rock-formations : very rarely in mineral veins or in crystalline rocks. In Central Canada, it is found somewhat abundantly in the interior of small cavities in the Black River or Trenton limestone of Kingston; and also, with crystals of dolomite, gypsum, fluor spar, blende, and other minerals, in cavities in the Niagara limestone, as in the vicinity of the Falls, around Owen Sound, on Drummond Island, and on the Grand Manitoulin, Lake Huron. Celestine

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is the principal source of strontia salts, used in pyrotechny to impart a red colour to rockets and signal lights, and for laboratory purposes.

98. Gypsum (Hydrous Sulphate of Lime, Sclenite. &c.) :- White, grey, yellowish, pale-red, &c. Monoclinic in crystallization, the crys-

tals very commonly as in Fig. 79 a, or in arrowheaded twins as in Fig. b, also in lamellar and foliated erystalline masses with strongly pronounced cleavage in one direction, and in fibrous and granular masses, the latter often forming rock deposits. The cleavage planes present a more or less pearly aspect, the other crystal-faces exhibit-



ing a vitreous or pearly-vitreous lustre. Granular and rock varieties have mostly a dull earthy aspect. H = 1.0 - 2.0; sp. gr. 2.25 - 2.35. Sectile, and, in thin lamellæ, somewhat flexible. Becomes opaque when held at the edge of a lamp or candle-flame. <u>BB</u>, exfoliates, and melts into a white caustic enamel. In the bulb-tube yields a large amount of water. Soluble in hydrochloric acid. Dissolves also, if in fine powder, in a large amount of water, and more readily in a solution of rock salt. Normal composition: sulphuric acid 46.51, line 32.56, water 20.93. The transparent crystals and cleavable varieties are commonly termed sclenite; and the fibrous and fine granular varieties form the alabaster and satin spar of lapidaries, but these names are also bestowed on similar varieties of earbonate of lime. When deprived of its water by exposure to a low red heat, gypsum is converted into plaster, or Plaster of Paris.

Crystalline and fibrous masses, and occasionally distinct crystals of gypsum, associated with crystals of quartz, dolomite, &c., occur in cavities of many of the Silurian strata in Canada, and thin bands are interstratified in places with the shales and limestones of some of these formations. Gypsum occurs under these conditions in the Calciferous formation of Beauharnois, the Hudson River formation of Point Rich on Georgian Bay, the Medina formation of St. Vincent, and in the Clinton and Niagara strata in the vicinity of the Falls, Hamilton, Dundas, and elsewhere.

Rock masses of granular and compact gypsum, more or less mixed with carbonate of lime, characterize the Onondaga Formation of Western Canada, and occur largely in the valley of the Grand River : more especially in the townships of Dumfries, Brantford, Oneida,

SULPHATES.

Sences, and Cayuga; as well as throughout the tract of country, generally, between the eastern extremity of Lake Eric and the mouth of the Saugeen. (See under the Onondaga Formation, in Part V.) The greater part of the gypsum from these localities is ground for agricultural use. The present annual produce amounts to about 15,000 tons.

99. Epsomite (Epsom Salt) :- White or greyish. Soluble : taste, strongly bitter. Trimetric in crystallization, but occurring, in nature, chiefly in fibrous tufts and earthy or botryoidal incrusting masses. H = 2.0, or less. BB, runs at first into liquid fusion, and then forms an alkaline infusible crust which assumes a flesh-red colour if moistened with a drop of nitrate of cobalt and again ignited. Yields a large amount of water in the bulb-tube. Normal composition : sulphuric acid 32 52, magnesia 16.26, water 51.22. Occurs in Canada, as an efflorescence or incrustation, on exposed surfaces, and on the edges of the planes of bedding, of shales and other strata, where it is formed apparently by the action of percolating water containing soluble matters derived from the decomposition of pyrites. It occurs thus in some of the slaty talcose layers associated with the iron ores of Marmora, and also on the zeathered shales of the Utica series, near Montreal, Quebee, and Collingwood; and still more abundantly on some of the dolomitic beds of the Clinton and Niagara Formation, as near Dundas and elsewhere. Sulphate of magnesia occurs also in solution in the Tuscarora water, and in some other mineral springs.

100. Iron Vitriol (Green Vitriol, Copperas, Melanterite, &c.):-Pale-green, greenish-white; brownish-yellow by partial decomposition. Monoclinie in crystallization, but occurring mostly in efflorescent crusts and minute hair-like indistinct crystals. Soluble: taste, inky and metallic. H=2.0 or less. BB, blackens and becomes magnetic. In the bulb-tube yields a large amount of water, and gives off sulphurous acid. The aqueous solution gives a deep-blue precipitate with "red prussiate of potash;" and in general also with the yellow prussiate, from the presence of more or less sesquioxide of iron. Normal composition: sulphuric acid 28.8, protoxide of iron 25.9, water 45.3. Occurs on decomposing pyrites and marcasite, and on the exposed surfaces of rocks in which these minerals are present. It is thus found, in small quantities, ou many of the ores from the mineral veins of Lake Superior, Lake Huron, the Hastings region, and other parts of Canada. A specimen of iron pyrites from the Galway Lead Mine in the northern

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part of the county of Peterborough, became covered in the course of a few weeks with delicate tufts of minute acicular crystals of this mineral.

101. Nickel Vitriol (Morenosite) :--Pale-green, greenish-white. In efflorescent tufts of minute crystals on nickel ores. Soluble: taste, strongly metallic. BB, evolves sulphurous acid, swells up, and forms a dark grey mass. With borax, gives reactions of nickel oxide (see Part I). In the bulb-tube yields a large amount of water. If free from iron, the aqueous solution does not yield a blue precipitate with red or yellow "prussiate of potash." Normal composition: sulphurie acid 28.5, oxide of nickel 26.7, water 44.8. Detected by Dr. Sterry Hunt, as an efflorescence on an arsenical nickel ore from the Wallace Mine, Lake Huron. (See No. 17, above.)

102. Alum :---Normally, white, but sometimes stained of a yellowish or brownish colour by sesquioxide of iron and other impurities. Mono. metric in crystallization, but occurring commonly in earthy efflorescent crusts. Soluble : taste, sharp and more or less bitter. BB, froths up and forms a white earthy mass which assumes a fine blue colour if moistened with a drop of nitrate of cobalt, and again ignited. Normal composition : sulphuric acid 33.75, alumina 10.82, potash 9.95, water 45.48. Occurs in considerable abundance on the exposed face of some high bluffs of argillaceous shale (belonging to the lower portion of the Upper Copper-bearing series) on Slate River, a tributary of the Kaministiquia, about twelve miles west of Fort William, Lake Superior.

L. PHOSPHATES AND ARSENIATES.

[These compounds are composed of phosphoric acid or arsenic acid, or of the two combined, with various bases. They present a vitreous or other non-metallic aspect. Phosphates when moistened with a drop of sulphuric acid (and many without this addition), impart a green colour to the point of the blowpipe flame. When fused, in powder, with carb. soda in a platinum spoon, an alkaline phosphate is formed, solable in water. The clear solution decanted from the insoluble residuum, yields a canary yellow precipitate with a drop or two (or small fragment) of nitrate of silver. The excess of carbonate of soda in the solution may be previously decomposed by the addition of a drop or two of nitric acid, but this is not actually necessary in ordinary cases, and it is essential to have the solution neutral or slightly alkaline-Arseniates, when mixed in powder with some carb. soda, and ignited

PHOSPHATES.

on charcoal in a reducing flame, emit a very distinct odour of garlie. Canadian examples, of this group, amount to only three in number, as given below; but, one of these, the lime fluor-phosphate, Apatite, occurs in comparative abundance, and is a substance of much commercial value.

103. <u>Apatite</u> (Phosphate of Lime) :--Green, blueish-green, violetred, rose-red, brownish, greenish-white, &c.--shades of green and dullred being often present in the same specimen. Lustre, <u>vitreous</u> and vitreo-resinous, with frequently a slight opalescence on one of the cleavage planes. Crystallization, <u>Hexagonal</u>: the crystals consisting most commonly of <u>six-sided prisms</u>, often of large size, and frequently

with rounded edges. Occurs also in lamellar cleavable masses, which sometimes form rock beds of considerable extent; also occasionally in globular and other shapes with fibrous structure. H = 4.5 - 5.5, normally 5.0. Sp. gr. 2.9 - 3.3, most commonly about 3.18 to 3.2. BB, in most cases quite infusible, but some varieties

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vitrify slightly at the point of the assay-fragment after exposure to a long-sustained blast. The powder moistened with sulphuric acid, tinges the flame-point distinctly green. Dissolves readily in borax and phosphor-salt, forming a glass which becomes opaque on cooling or when flamed. (Sec, under the description of blowpipe-reactions in Part I). Easily soluble in nitric or chlorhydric acid. The diluted solution, saturated with ammonia, yields a copious white precipitate of phosphate of lime. This precipitate assumes a canary-yellow tint if treated with a solution of nitrate of silver, or if a crystal of that substance be laid in it whilst still moist. The presence of phosphoric acid may also be rendered evident in the diluted nitric acid solution by the formation of a clear-yellow precipitate with molybdate of ammonia.* Apatite consists essentially of phosphate of lime (or calcium, phosphorus, and oxygen) combined with in general about 8 or 10 per cent. of fluoride of calcium or chloride of calcium, or with a mixture of both, the fluoride usually preponderating. Canadian examples appear to be

^{*} The test-solution is prepared by dissolving some of the crystallized molybdate in a very small quantity of water, nitric acid being added to the solution until the cloudiness or thick precipitate, which forms at first, becomes redissolved. When this is added to the solution of the mineral, the whole must be gently warned. A yellow coloration, succeeded by a yellow precipitate, then quickly ensues.

essentially fluor apatites. The normal composition of an apatite of this kind is equivalent to : phosphoric acid 42.26, lime 55.60, fluorine 3.37; or, phosphate of lime 92.26, fluoride of calcium 7.74.

Extensive deposits of this mineral, chiefly in the form of veins, occur in the Laurentian strata of North Burgess and North Elmsley in the County of Lauark. These veins cut the enclosing strata transversely, and vary in width from an inch or two, to several feet (see Part V). The apatite, in crystals, and in cleavable and granular masses. is associated with mica, pyroxene, and other minerals. Where the veins occur in contact with crystalline limestones, these latter contain in many places detached crystals and grains of apatite, with occasional beds or lenticular masses of that substance.* Apatite occurs also in connexion with crystalline limestone, associated with fluor spar and octahedrons of black spinel, in the township of Ross in Renfrew County on the Ottawa; and with quartz and calcite, at Calumet Falls. Transparent pink and purple crystals are also reported by Dr. Sterry Hunt to occur in association with crystals of augite in a mass of erupted dolerite (see Part III) at St. Roch on the River Achigan. Apatite has likewise been found, in a quartz vein earrying copper pyrites and native copper, with large plates of white mica, in the township of Burford, in the metamorphic district south of the St. Lawrence (Part V).

Finally, it may be observed, small nodular masses consisting in great part of phosphate of lime, mixed with carbonate of lime and magnesia, sand, and other matters, are scattered through a conglomerate of the (Lower Silurian) Chazy formation at the Allumette Rapids; and similar nodules occur in limestone strata of the same formation in the townships of Hawkesbury and Lochiel, west of the Ottawa; as well as in strata of the Quebec group at Point Lévis, and on the River Ouelle. These phosphatic nodules present a chocolate or blackish-brown colour,

^{*} Most of the large apatite crystals from this locality are simple hexagonal prisms, merely terminated by horizontal cleavage-planes; but the more perfect examples exhibit a combination of great rarity in the crystallization of this mineral. Some large crystals recently obtained by the author from veins on the north shore of Rideau Lake, consist of hexagonal prisms terminated at the free extremity by a simple hexagonal pyramid, without any appearance of the usual basal plane. This simple combination has hitherto been seen only in the so-called *spargelstein* from the mountains near Jumilla in the south-cast of Spain, and in the searcely cleavable variety known as *moravite* from Arendal in Norway. In the Rideau crystals, the planes of the pyramid meet the adjacent prism-planes at an angle of 130° as measured approximatively by the hand gonlemeter.

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and contain in some cases fragments of the shells of lingula (see Part IV) and other organic bodies. They are supposed to be coprolites or fossilized excrementous matters. When heated, they emit an odour of burnt animal matter, and evolve ammonia. Phosphate of lime, whether derived from inorganic or organic sources, constitutes an agricultural fertilizer of the highest value.

104. Vivianite (Hydrated Phosphate of Iron) :---Blue, blueish-green (normally, colourless, but becomes blue on exposure); streak paleblue or blueish-white. Monoclinic in crystallization, with very perfect cleavage in one direction, but found more commonly in bladed and fibrous varieties, and in earthy masses, often forming, when in the latter condition, beds or layers of a certain extent. H = 1.0 - 2.0; sp. gr. 2 55 - 2.7. BB, tinges the flame-point pale-green (from presence of phosphoric acid), and yields a dark magnetic globule. In the bulb-tube gives off a large amount of water. Normal composition : phosphoric acid 28.30, iron protoxide 43.00, water 28.70, but the iron in the coloured varieties is always partly in the state of sesquioxide, and the earthy varieties moreover are usually mixed with a certain amount of clay, sand, iron ochres, manganese ochre, or other foreign matters. In Canada, this mineral has only been found in an earthy condition, underlying a bed of bog iron ore, in Vaudreuil, on the Lower Ottawa.

105. Cobalt Bloom (Erythrine, Arseniate of Cobalt) :--Occurs only (as regards Canada) in the form of a slight efflorescence or incrustation, of a peach-blossom red colour, on the silver-holding cale spar of Prince's Location, on the north-west shore of Lake Superior; and also, but in traces only, in the more recently discovered silver-bearing vein near Thunder Cape. Normal composition: arsenie acid 38.25, oxide of cobalt 37.85, water 23.90; but sometimes mixed with arsenious acid.

IV. FLUORIDES AND CHLORIDES.

[This subdivision comprises the compounds of Fluorine and Chlorine, respectively, with metallic bases, such as sodium, calcium, aluminium, lead, silver, and the like. These compounds present a nonmetallic aspect; and they exhibit a general resemblance, also, in other characters, to many so-called oxygen salts, more especially to certain
phosphates, borates, carbonates, and sulphates. Amongst Canadian minerals, however, as at present discovered, we have but a single representative of each group.]

A. FLUORIDES,

[The only Fluoride as yet discovered in Canada, is the fluoride of calcium, long known under its popular name of Fluor Spar. In a strictly natural classification, this mineral should occupy a place in the immediate vicinity of the Apatite and Calc-Spar groups. The fluorides generally, when treated, in powder, with hot sulphurie acid, evolve fumes of fluo-hydric acid which exert a strongly corrosive action on glass. The powdered substance may be warmed with some strong sulphuric acid in a platinum or lead crucible covered with a glass plate, when the under surface of the latter will be quickly corroded. In making the experiment, great care must be taken not to inhale the evolved fumes, as these are highly injurious. (See also under "Blowpipe Reactions," in Part I.)

106. Fluor Spar :- Occasionally colourless, but more commonly violet or amethyst-blue, dark blueish-green, pale-green, pale blueishgrey, yellow, brownish, or rose-red, the edges and angles of many crystals being more deeply tinted than the other parts, or sometimes presenting a distinctly different tint or shade of colour. Streak, white. Crystallization, Monometric; the crystals mostly cubes, or cubes with bevelled edges (Figs. 80, 81). The corners of these cubes break off very readily, in consequence of the strongly-pronounced octahedral cleavage possessed by the mineral. H = 4.0; sp. gr. 3.1 - 3.2. Emits a blueish or other coloured phosphorescent light, when moderately heated in the form of powder. BB, generally decrepitates violently (see Part I), and fuses into an opaque white bead which becomes caustic after strong ignition. Decomposed, with evolution of corrosive fumes, by hot sulphuric acid. The evolved fumes consist of fluohydric acid which strongly corrodes the surface of glass. Average composition: fluorine 48.72, calcium (the metallic base of lime) 51.28.

Fluor Spar occurs very generally in association with metallic ores in veins. It also forms *per se*, or in connection with calcite, the substance of many narrow veins;



CIILORIDES.

and it occurs likewise in cavities and small fissures in limestone and other rocks, and is occasionally disseminated through beds of crystalline limestone. The finest examples hitherto discovered in Canada, have been obtained from a large vug or eavity in a vein of amethystquartz on the north-east shore of Thunder Bay, Lake Superior. The fluor spar from this spot forms large cubes of two or three inches in diameter, which rest on equally large pyramids of amethyst-quartz, and are coated with iron pyrites in minute eubes, the whole being surmounted, here and there, by scalenohedrons of calcite. The fluor spar is partly of a pale greenish tint, but mostly of a violet or amethystine colour. Pale green and purple cubes occur also in most of the metalliferous veins of Thunder Bay and the surrounding region, mostly with quartz, caleite, blende, galena, and copper and iron pyrites, as at Prince's Mine, the Shuniah Mine, in several veins in the township of Neebing, and in others near Black Bay and Terrace Bay, on Fluor Island in Neepigon Bay, and elsewhere. Also in amygdaloidal greenstone, near Cape Gargantua. Fluor spar occurs likewise, according to Mr. Murray, in association with specular iron ore, in crystalline limestone on Lake Nipissing. It occurs also, with apatite, in crystalline limestone in the township of Ross, in Renfrew county on the Ottawa, and elsewhere in that district. Also in veins, with galena and ealcite, in Trenton limestone in contact with gneiss at Baie St. Paul; and in narrow veins in the Trenton limestone of the vicinity of Montreal, and the Utica slates of Quebec. Small crystals have likewise been obtained, from fissures and cavities of the Niagara strata, in the neighbourhood of the Falls.

B. CHLORIDES.

[This group is represented in Canada by a single type, the highly important Chloride of Sodium, or Rock Salt. The presence of chlorine in mineral bodies is easily ascertained by the blowpipe. Some phosphor-salt, with a few particles of black oxide of copper, is fused in a loop of platinum wire, so as to produce a deeply-coloured glass. To this, a small portion of the test-substance, in powder, is added, and the glass during fusion is held just within the point or edge of the flame. The latter, if chlorine be present, will assume a rich azure-blue colour from the volatilization of chloride of copper. Many chlorides are soluble in water. None possess a metallic lustre, nor is the degree of hardness in any species sufficient to scratch ordinary glass.]

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107. Rock Salt :--- Coleurless, and also variously coloured by accidental impurities, as sesquioxide of iron, organic matters, &c., the imparted tints being mostly red, brownish, violet-blue, yellowish, or

pale-green. Streak, white. Crystallization, Monometric: the crystals usually cubes, often with hoppershaped depressions on each face—the larger crystals being composed of numerous minute cubes so arranged as to produce this peculiarity. Occurs also in lamellar and granular masses. Cleavage, cubical. H = 2.0 -2.5; sp. gr. 2.1 - 2.25. Taste, strongly saline. Ab-



sorbs moisture from the atmosphere. BB, decrepitates strongly (unless very dry), and melts into an opaque bead, which colours the outer flame intensely yellow. Normal composition: chlorine 60.66, sodium 39.34; but usually, small portions of chloride of magnesium and calcium, and sulphates of lime, magnesia, and soda, are also present. Most samples contain likewise a certain admixture of clay or other impurities.

A deep boring on the bank of the River Maitland near the town of Goderich, commenced at the close of 1865 in quest of rock oil, has yielded an abundant supply of strong brine of remarkable purity-thus indicating the presence of a very extensive deposit of salt, below this section of the country. The boring has been carried down from the surface gravel and underlying Corniferous Formation, into and apparently through the Gypsiferous or Onondaga strata (see Part V), the total depth from the surface being a little over one thousand feet. According to Mr. Platt, who conducted the boring, salt in solid layers was reached at 964 feet from the surface, and the total thickness of these layers, exclusive of some thin partings of salt-bearing clay, averages about thirty feet. An analysis of the brine by Dr. Sterry Hunt, shews it to be a saturated solution, containing over 26 per cent. of saline matter: 25.90 (equal to 99.018 per cent.) of this, being pure salt or chloride of sodium. (See Geol. Reports for 1868 and 1869, for various comparative analyses, and much valuable information on the Goderich and other brines, by Dr. Sterry Hunt.) Salt has also been subsequently reached by other borings at Kincardine, Clinton, and Seaforth, in the same district. At Seaforth, from information received from Dr. N. Coleman, a more or less solid bed was struck at a depth of about 1040 feet. Chloride of sodium occurs also in solution in

CARBONACEOUS SUBSTANCES.

143

many of our mineral springs, but only in small quantity, and always accompanied by much chloride of calcium or chloride of magnesium, sulphate of lime, and other salino compounds, which interfere with its separation for economic purposes. The Hallowell Spring contains from $3\frac{1}{2}$ to nearly 4 per cent.; the St. Catharines' water, about 3 per cent.; and other springs, still lower amounts. Quite recently, an announcement of the discovery of rock salt in the township of Combermere in Renfrew County, has been made in the newspapers, but this requires verification. In all probability, the mass said to have been found, was placed there by some of the earlier settlers to prevent cattle from straying in the woods, or by hunters to attract deer. Large masses of rock salt are brought by Quebec ships from Liverpool, in ballast; and blocks of this salt, taken into the woods, have often given rise to pretended discoveries. A block of 50 or 60 lbs. weight will remain undissolved for many years.

V. BODIES OF ASSUMED ORGANIC ORIGIN.

This division includes many salts, resins, coals, and other carbonaceous matters, to which an organic origin is generally attributed; but the supposed derivation of all matters of this kind from organic bodies is by no means free from doubt. The group is represented in Central Canada by a single salt, an oxalate, and by two or three earbonaceous substances, one of which, the fluid petroleum or rock-oil, is of great economic value.

A. OXALATES.

108. Humboldtine (Oxalate of Iron) :--Only known, in Canada, as a yellow incrustation on the bituminous (Devonian) shales of Kettle Point or Cape Ipperwash in the township of Bosanquet on Lake Huron. BB, becomes black and magnetic when gently heated, and is finally converted into red oxide of iron. In the bulb-tube, blackens, and yields a large amount of water. Normal composition: oxalic acid 42.40, protoxide of iron 41.13, water 16.47.

B. CARBONACEOUS SUBSTANCES.

109. Petroleum or Naphtha (Rock Oil) :—Fluid, passing into a semifluid and viscous condition. Colour, yellowish-brown or brownish-black in petroleum; pale-yellow, occasionally with a blueish tinge, in naphtha. Highly inflammable. Essential composition: carbon 83 - 88per cent., hydrogen 12 - 17 per cent. Occurs in rocks of various

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kinds and of different periods of formation, and is usually thought to have originated from the slow decomposition of imbedded vegetable and animal matters. This view, however, is exceedingly problematical as applied to petroleum generally : regard being had to the enormous quantities of this substance occurring in so many different parts of the earth; to the unceasing flow of vast numbers of petroleum springs in many localities, age after age, from the earliest periods of history; to the fact that petroleum occurs in many rock-formations-even in ancient gneissoid strata-which lie far below the great Carboniferous and Devonian series (the first, apparently, in which land vegetation has been detected); and to the absence in petroleum-bearing rocks of any special organic remains or peculiar characters suggestive of naphtha-form. ing capabilities, as compared with strata in which petroleum has not been found. Regard being had to these and other related facts, discussed more fully in Part V of the present work, it is searcely possible to refer the enormous quantities of petroleum stored up in subterranean reservoirs, or poured out in flowing springs from age to age, simply to the decomposition of sea-weeds or the soft parts of ordinary mollusea, radiata, or lower types, entombed in rock deposits : evidences of these organic bodies being wanting, moreover, in many petroleumholding rocks, and being far less abundant in others than in various trata in which no traces of petroleum are met with. It might be pretended, with almost an equal show of probability, that all the water on the earth had come from organised bodies, simply because these bodies contain or yield water. A suggestion of this kind would probably have been attempted, if water were a substance of comparatively limited occurrence.

In the Province of Ontario, petroleum occurs abundantly in springs or wells, arising apparently from reservoirs in the Corniferous (Devonian) Formation, in many parts of the region lying between the more southern point of Lake Huron and the north-west shore of Lake Erie: more especially in the township of Enniskillen; and, less abundantly, in Oxford, Mosa, and Dereham. Small quantities have also been obtained from a well in the Utica (Lower Silurian) Formation of the Great Manitoulin Island in Georgian Bay—the shales of this Formation, both there and elsewhere, being more or less saturated with bituminous matter, and thus yielding petroleum on distillation. Many of the calcarcous strata of the Niagara, Trenton, and other Silurian

CARBONACEOUS SUBSTANCES.

Formations, are also more or less bituminous; and liquid and viscous petroleum is occasionally found in the cavities of fossil shells, enclosed in these beds, as well as in fossilized corals, &c., of Devonian rocks. Petroleum springs occur likewise in the Devonian strata of Gaspé in Eastern Quebec, as near Douglastown on the St. John River, and on a branch of a small stream known as Silver Brook in the adjacent country, as first made known by the officers of the Geological Survey. Viscous petroleum is cited also, in the Geological Report for 1863, as occurring in cavities, many of which are lined with chalcedony, &c., in a greenstone dyke at "Tar Point" in Gaspé Basin. Indications of petroleum or asphalt have also been noticed in other eruptive dykes of that region.

110. Asphalt :- Black, blackish-brown. In solid and also in spongy or semi-viscous masses. If, in the solid varieties, = 1.0 - 2.0; sp. gr. 1.0 - 2.0. Very inflammable — melting easily, and burning with a yellow flame and emission of bituminous odour. Consists essentially of Carbon, Hydrogen, Oxygen, and Nitrogen, in somewhat variable proportions. In many if not in all cases, asphalt is derived from petroleum, the two substances passing into each other by insensible transitions. Petroleum thickens and assumes a darker colour under certain conditions of exposure, and finally becomes solid and partially oxidized. The so-called "gum beds" or "mineral-tar deposits" of Enniskillen may be referred to this variety. These beds, which have evidently resulted from the drying up of ancient overflows of petroleum, occupy, in the southern part of the township, two detached areas of about an acre, each, in extent; and they present a thickness varying from a couple of inches to two feet. A small deposit, covered by ten or twelve feet of drift clay, and resting on gravel, occurs in the northern part of the township. This deposit is partly of a leafy texture, somewhat resembling the so-called "paper coal" from the lignite deposits of the Rhine, &c., and its shaly layers exhibit the impressions of leaves and insects in various places. Being mixed moreover with much earthy matter, or "ash," the deposit has all the characters of a small coal-seam.

111. Anthraxolite : — Black, lustrous, resembling anthracite in general characters, but very brittle. H = 2.25 - 2.5; sp. gr. 1.35 — 1.55. Generally decrepitates when heated. BB, a small fragment loses its lustre, but exhibits no further change. Composition, essen-

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tially, carbon, with from 3 to 25 per cent. of volatile matter, including a small amount of moisture. The ash, as at present observed, varies from 0, to 10 or 11 per cent. When present, it exhibits under the microscope no trace of organic structure. This substance, in all probability a product of alteration from petroleum or asphalt, occurs narrow veins in rocks of various kinds, and in small masses and t layers or coatings in strata of the Utica and other formations. Occarionally also, it is found in the interior of orthoceratites and other fossil shells. As it differs essentially by these conditions of occurrence from anthraeite proper, the name anthraxolite has been given to it, but simply as a convenient term for present use. It occurs in narrow veins, associated with quartz, amongst the altered strata of Lotbinière, in the Eastern Townships; and also, in regularly banded veins with quartz and iron pyrites, in strata of the same general age, on Thunder Bay, Lake Superior. A variety from the latter district, shewed a sp. gr. of 1.43, and gave the writer : moisture 2.08, additional loss in closed vessel 3.56, ash 0.00, fixed carbon (by difference) 94.36 (Canadia-Journal, vol. x, 411). The substance occurs likewise in narrow brok veins, or filling small cracks, per se, at Acton and other localities in the Eastern Townships, as well as on the Island of Orleans, at Beauport and Point Levis near Quebec, and elsewhere in the neighbourhood of the latter city. The variable percentage of volatile matter (exclusive of moisture) is evidently due to the greater or less amount of alteration to which the original bituminous matter has been subjected.

112. Coal:—Black (often with iridescent tarnish) in anthracite and bituminous coal; brown, in brown coal or lignite. H = 1.0 (or less) --2.5; sp. gr. 1.0 - 1.7. BB, anthracite is scarcely altered; bituminous coals take fire, and many exhibit a kind of fusion. True coal, in its different varieties, occurs in regular beds or layers, mostly associated with bituminous shale, nodules of iron-stone or impure carbonate of iron, and numerous fossilized plants. Anthracite consists almost wholly of carbon (exclusive of a small amount of mineral matter or "ash"). Anthracitic coals contain, in addition, a small percentage of hydrogen, oxygen, and nitrogen; and in bituminous coals, these components are more largely present. Many coals also contain sulphur, derived in chief part, or perhaps wholly, from intermixed pyrites. (See a communication by the writer, on the Assaying of Coals by the Blowpipe, in Canadian Journal, vol. iii, 208.) A thin seam of bituminous coal

CARBONACEOUS SUESTANCES.

occurs in the Devonian sandstones of Gaspé, the only known locality within the old limits of Canada in which true coal has been found. This is referred to more fully in Part V. A description of the great coal fields of Nova Scotia, &c., will be found in the "Acadian Geology" of Dr. Dawson, and in other publications on the geology of the Maritime Provinces.

113. Peat :- This substance is simply vegetable matter-consisting chiefly of semi-aquatic mosses-in a peculiar state of decomposition. It presents in its more typical form, a brown or blackish-brown colour, with an earthy, or, in places, a sub-slaty or sub-fibrous, texture. Sp. gr. 0.33 - 1.05. Inflammable, burning with a pleasant odour and yellow flame. Composition, essentially carbon, hydrogen, oxygen, and a large amount of water (in dried peat, nominally from 15 to 25 per cent.) with from 2 or 3 to 10 or 12 per cent. of mineral matter or ash. This valuable substance, occurs in large beds of more or less modern origin, in various parts of Ontario and Quebec, mostly overlying deposits of shell-marl. The principal localities lie within the townships of Humberstone and Wainfleet on Lake Erie; Sheffield in Addington County; Beckwith, Huntly, Calbourne, Westmeath, Nepean, Gloucester, Cumberland, Clarence, Plantagenet, Roxborough, Osnabruck, and Finch, between the west bank of the Ottawa and the St. Lawrence; Grenville, Harrington, Mille-Isles, and adjacent localities on the east side of the Ottawa; the Seigniories of Assumption, St. Sulpice, Lavaltrie, and Lanoraie, on the north shore of the St. Lawrence, above Lake St. Peter; St. Etienne, Champlain, and other places between the St. Maurice and Quebee; Sherrington, Hemmingford, Longueuil, Ste. Marie de Monnoir, Stc. Roselie, and other localities on the south shore of the St. Lawrence; the Seigniories of Rivière Ouelle and Rivière du Loup, farther east; near the Métis, Rimouski, and Madaswaka Rivers, in Gaspé; and largely in the Island of Antieosti. Peat in a properly dried and compressed condition, has been shown of late years to form a good fuel for the use of locomotives, and also for many metallurgical operations, being especially available, on account of its general freedom from sulphur, in the smelting of iron ores.

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PART III

ROCKS, AND ROCK-PRODUCING AGENCIES.

I. GENERAL CLASSIFICATION OF ROCK MASSES.

The term "rock," in its geological acceptation, includes all the stony and earthy masses-whether consolidated, as granite, limestones, &c., or composed of loosely coherent particles, as sands and gravels-which make up the outer or visible portion of the earth. The mean radius of the earth-mass, or distance from centre to surface, is equal to 3956 miles. The elevations and depressions which occur upon the earth's surface, forming mountain-chains and table-lands, valleys and the beds of seas and lakes, are thus, as compared with this radius, of but slight significance. It is necessary to bear this in mind, in order that we may not exaggerate the intensity of the natural forces by which these inequalities have been produced. In a section or profile in which the same scale is employed for longitudinal and vertical dimensions, the greatest inequalities become scarcely apparent. In order to render evident the differences of level existing between separate points, it is necessary in engineering drawings, and in ordinary geological diagrams, to use a greatly exaggerated scale for heights or depths as compared with horizontal distances; and the eye unconsciously follows a somewhat similar process in taking in the contour-lines or general aspect of a mountainous region.

Our knowledge of the internal condition of the earth is necessarily to a great extent conjectural; but the weight of evidence, collected in reference to this subject, leads to the conclusion that the earth-mass, from surface to surface, is not throughout a perfectly solid body. In the opinion of some investigators, the central portion is solid, and

between this and the consolidated surface-layers a zone of fluid or vaporous matter exists. According to others, the earth-mass is more or less consolidated throughout, but with enormous cavities, here and there, filled with molten or fluid matter. The more commonly received opinion, again, infers the surface rocks—technically known as the earth's crust—to extend downwards to merely a limited depth, whilst the whole of the internal portion is in a condition of igneous fluidity. These views are practically identical, in so far as they assume the presence of fluid or vaporous matter, and the existence of a high temperature, at a certain depth beneath the surface rocks; and they are sustained, more especially, by the following data:

• Careful observations made in various parts of the world, shew that a constant temperature is maintained throughout all periods of the year, at a certain depth beneath the earth's surface. This depth varies in different localities, and especially where different kinds of rock occur, but it averages in temperate elimates about 100 feet. At lower levels the temperature is found invariably to increase with increase of depth. The ratio of increase is not uniferm, being greater or more rapid in some places than in others: but an actual and marked vise of the thermometer from point to point, below the zone of constant temperature, is always observable. The mean ratio of increase, at the limited depths to which researches have been carried, may be assumed to equal about 1° . Fahrenheit for each descent of 60 feet. At this ratio even, and we may reascnably infer that it would be much accelerated at lower levels, a temperature sufficiently high to maintain most mineral substances in a state of fusion, or in part even in a vaporous condition, would soon be reached.

2. Water brought to the surface from great depths by narrow bore-holes commonly known as Artesian wells, always exhibits a higher temperature than the mean temperature of the locality; and if a boring be increased in depth, the temperature of the water becomes also increased.

6. <u>Active volcances</u>, which may be regarded as channels of communication between the surface and the internal parts of the earth, are more or less constantly pouring forth, from unknown depths, vast streams of molten rock or lava, accompanied by other products of igneous action. About two hundred and seventy volcances are now known to be from time to time in eruption, and many others are apparently in a permanently quiescent state. Eruptions also frequently take place on the bed of the sea.

(1) Certain rock-masses, in districts now remote from centres of volcanic action, have evidently been forced upwards, from deeply-seated sources, in a molten or more or less incandescent state, amongst previously consolidated rocks. The latter exhibit at the points of contact, and for some distance beyond, changes of colour, and other effects, that can only have resulted from the direct

(5) Hot Springs

or indirect action of heat. These effects are not seen in all cases of rock-intrusion, but in the great majority of instances they have undoubtedly occurred.

In different localities, as a general rule, the rocks which form the surface of the ground, or which become visible to us on the sides of cliffs and river-banks, in quarries, railway cuttings, and the like, are more or less distinct in composition and other characters. This must be familiar to the most casual observer. Thus, around the Falls of Niagara, and extending far and wide across that section of the Province, we find vast beds of dolomitic or magnesian limestone presenting several varieties of texture. About Hamilton and Dundas, with other rocks, ferruginous shales and beds of red and grey sandstones are seen At Toronto, our rock-masses consist of layers of gravel and elay, overlying grey and greenish sandstone-shales. Near Collingwood, and again at Whitby, we observe dark-brown, highly-bituminous shales, containing the impressions of trilobites and lingulæ (see Part IV), often in great numbers. At Kingston, we meet with limestone rocks differing from those of the Niagara district, and giving place, as we proeccd north and east of the city, to beds of erystalline rock of granitic aspeet, geologically known as Gneiss. Some of the "Thousand Islands" consist of very ancient sandstone resting on gneiss. At Montreal, with beds of limestone, &e., we see, in the pieturesque Mountain, a dark, massive or unstratified rock, a variety of the Trappean series, more or less closely allied to the lavas of volcanie regions; and rocks of a similar kind occur largely on the north shore of Lake Huron, and around Lake Superior, as well as in the Eastern Townships and other parts of Canada.

These examples are sufficient to shew the diversity which prevails with regard to the rock-matters of comparatively neighbouring localities. But if we look, not to the mineral characters of rocks, but to their general conditions of occurrence, by which their respective origins or modes of formation are indicated, we may refer them to two leading groups or sub-divisions, connected by an intermediate group, as in the following scheme :

A SEDIMENTARY ROCKS-or Ordinary Stratified-Formations.

METAMORPHIC ROCKS- or Stratified Crystalline Formations.

B ERUPTIVE OF UNSTRATIFIED ROCKS.

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Sedimentary strata, comprising ordinary sandstones, limestones, &c.,

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consist of detrital or other materials, collected, and arranged in more or less regular layers, by the action of water, as described below. Metamorphic strata are regarded as consisting wholly or in great part of sedimentary deposits that have been altered or rendered crystalline by heat or chemical agencies. Eruptive rocks are known in many instances to have cooled down from a state of fusion, and are thought in others to have been consolidated from a plastic condition due to aqueo-igneous agencies. They have been formed, or have been brought into this condition, beneath, or deeply within, the Earth's crust, and have been forced upwards from time to time through fissures in the overlying rocks. In each of these divisions—Sedimentary, Metamorphie, and Eruptive—the included rocks belong to various periods of formation.

II. SEDIMENTARY ROCKS.

The rocks of this division make up by far the greater portion of the Earth's surface. Having been formed by the agency of water, they are often called <u>Aqueous Rocks</u>. They consist for the greater part of muddy, sandy, and other detrital sediments, collected by the mechanical action of water, and subsequently consolidated by natural processes, as described a few pages further on. Various limestones, however, and certain other rock matters of this division, have been deposited from waters in which their materials were chemically dissolved.

These sedimentary or aqueous rocks are characterized essentially by occurring in beds or strata; secondly, by exhibiting in many instances, a more or less clearly-marked detrital or sedimentary structure; and thirdly, by often containing organic remains. The latter, comprising shells, bones, leaf-impressions, &c. (see Part IV), are the fossilized parts of animals and plants which lived upon the Earth, or in its waters, during the periods in which these rocks were under process of formation, as described below.

The sedimentary rocks may be conveniently discussed under the following heads: (1) <u>Composition or mineral characters</u>; (2) <u>Modes</u> of formation; (3) <u>Subsequent changes and effects produced by gealo-</u>gical agencies.

COMPOSITION OF SEDIMENTARY ROCKS.

As regards composition, these rocks fall mainly under the following sub-divisions :

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SEDIMENTARY ROCKS.

Sandstones, sands, and gravels—or arenaceous rocks.

Clays and clay-slates-or argillaceous rocks.

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Limestones and Dolomites-or calcareous rocks.

Conglomerates and Breccias: rocks of variable composition (see below).

<u>Trap tufas</u>: stratified deposits formed out of materials derived from the denudation of trap and greenstone rocks.

Rock matters of carbonaceous origin, as the different kinds of coal.

To these may be added a few other substances of subordinate occurrence, as gypsum, rock-salt, and bog iron ore.

Sandstones are nothing more than beds of consolidated sand. They are of various colours, but chiefly present dull shades of yellow, red, brown, or green, and some are nearly pure white. The colouring matter is either sesquioxide of iron, or, in the case of the greenish varieties, a silicate of the protoxide. The harder and purer kinds, as some examples of our "Potsdam sandstone," are called *quartzose sand*stones. In other kinds, a certain amount of carbonate of lime is present, cementing together the component grains of sand, and forming calcareous sandstones. For special Canadian localities of these and other rocks mentioned under this division, consult Part V. Certain siliceous rocks, called "tripoli" and "infusorial marls," are formed almost entirely of the remains of diatoms, microscopic vegetable forms of low organization. (See Part IV.)

Clay Slates are merely consolidated clays. They have a fissile structure, and are mostly of a grey, greenish, brown, or black colour the dark tints being chiefly derived from the presence of finely disseminated carbonaceous or bituminous matter. Clays are also of various colours, as white, greenish, yellowish, blueish, black, and red. Those which contain little or no iron become white or pale yellow on ignition. Many clays are highly calcareous; others, bituminous, &c. The term shale is often applied to fissile consolidated clays; but this term, it must be remembered, is applied equally to fissile or slaty limestones and sandstones. When the term is used, therefore, the kind of shale should also be signified : as an argillaceous shale, an arenaceous shale, and so forth. Bituminous shales, as regards their mineral base, may be also arenaceous, calcareous, &c.

Limestones and Dolomites are principally, perhaps, of chemical formation. Water containing free carbonic acid (derived from decay-

ing vegetable matters, &c.) dissolves a certain amount of carbonate of lime, but the bicarbonate, thus formed, is easily decomposed by various natural agencies, even by mere exposure to the atmosphere, and a precipitation of calcareous matter takes place. In this manner, calcareous tufas (so common in many of our swamps, streams, &c.), together with stalactites and stalagmites, are produced; and similar processes, acting on a larger scale, may have given rise to extensive depositions of limestone strata in ancient seas and lakes. Some limestones, again, are formed almost wholly of the calcarcous shells or tests of erinoids, foraminifera, and other organisms (see Part IV) : but others are, undoubtedly, mechanical or rock deposits, derived from the wasting of coral reefs and older limestone formations. Limestones consist of carbonate of lime, more or less pure; dolomites, of carbonate of lime and earbonate of magnesia in equal atomic proportions; and dolomitic limestones of these two carbonates in other proportions, the lime carbonate generally predominating. Dolomites and dolomitic limestones appear in many cases to have been simple chemical precipitates, and, in others, to have originated from the alteration of limestone rocks by the action of soluble magnesian salts. These calcarcous rocks are of various colours: grey, white, black, yellowish, &c. Their texture is sometimes very close and uniform. At other times, the stone is made up of small spherical concretions, when the texture is said to be "oolitic." A bed of grey limestone of this structure occurs near the Chatte River in Gaspé. Oolitie limestones are of all geological ages. Some limestones, again, are of an earthy texture : the well-known chalk of Europe is an example; also our own "calcarcous tufa," or "shell marl." Many of the dark llmestones, as those of Niagara, &c., are more or less bituminous. Ordinary limestones dissolve in acids with strong effervescence; but the dolomites produce merely a feeble or slightly perceptible effervescence unless the acid be heated. Limestones which contain from 15 to 25 per cent. of argillalaceous matter in intimate admixture, yield hydraulie or water line-Beds of this kind occur at Thorold, Cayuga, Loughboro', Kingston, Hull, Quebec, and other localities. (See Part V.)

Conglomerates consist of <u>rounded pebbles</u> or masses of quartz, sandstone, &c., cemented together, or imbedded in a paste of finer sandstone, or other rock substance. They are often known as "Pudding stones." Examples are not uncommon amongst our Huronian and higher strata.

SEDIMENTARY ROCKS.

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Breccias consist of angular masses or fragments of rock, cemented together most commonly by calcareous matter. Whilst Conglomerates frequently contain imbedded water-worn materials derived from distant sources, true breecias are necessarily composed of detrital matters derived from neighbouring localities.

Trap-tu/as are of comparatively rare or local occurrence. They are made up of materials derived from the wasting of trap and greenstone rocks, and are mostly of a green colour, weathering red. Their texture is generally more or less uniformly fine-grained; but some occur as conglomerates and breecias, as on the north-castern shore of Lake Superior, and elsewhere.

The other rock-substances enumerated above—Coals, Gypsum, Rocksalt, and Bog Iron Ore—oceur only here and there as stratified rock deposits. For descriptions and Canadian localities, see Part I.

2 FORMATION OF SEDIMENTARY ROCKS.

The manner in which the ordinary sedimentary rocks, sandstones, shales, &c., have been formed, or built up as it were, is rendered clear by the observation of certain natural processes still in action. We find, for example, at the present day, that sediments of various kinds are constantly carried down by streams and rivers into lakes and seas, and are there deposited. We find, moreover, that the cliffs of many sea and lake coasts are being continually abraded and washed away by the action of the waves. Observation shows also, that the sedimentary matters thus obtained, are always deposited or arranged in regular layers or beds, and that they frequently enclose shells and sea-weeds, together with bones and leaves drifted from the land, and other organie Hence it is now universally admitted, that, with the excepbodies. tion of certain limestones and dolomites, beds of rock-salt, gypsum, coal, and some other chemical or organic deposits of small extent, all the sedimentary rocks have been formed directly out of previously-existing rock-masses, by the wearing away or destruction of these; and secondly, that they have all been formed or deposited under water.

In pursuance of this inquiry, consequently, we have to consider, first, the origin or derivation of the sediments of which these rocks are made up; and, secondly, the processes by which the consolidation of the sediments into rock, properly so-called, was effected.

The sediments of which these rocks originally consisted, were derived

from previously-existing rocks, by decomposing atmospheric agencies rain, frost, and so forth; by the action of streams and rivers on their beds; and by the destructive action of the waves and breakers of tho sea.

Action of the Atmosphere.-All rocks, even the most solid, are constantly undergoing decomposition and decay. The exposed face of a rock of any kind, for example, soon changes colour, and becomes in general more porous than the other portions of the rock. This effect is technically termed "weathering." Its action gives rise to the production of soils, and frequently causes the fossils contained in the rock to stand out in relief, these bodies being in many cases less easily destructible than the mass of the rock itself. Every shower of rain that falls, takes part in this decomposing or disintegrating action, and carries off something, in solution or suspension, to lower levels-id est, into streams, lakes, and seas. Frost, and, in certain localities, carbonic acid and other gases issuing through crevices in the rocks, assist this destructive process. Rain, acting on loosely coherent matters, is known in many districts to have excavated channels of considerable extent. These may become in course of time more or less permanent water courses, and the work of excavation be thus continuously carried on.

Action of Streams and Rivers.-The action of streams and rivers, in wearing their channels, is both chemical and mechanical. Calcareous river-beds are wasted bit by bit by the dissolving power of the water, especially during the autumnal season, when dead leaves and other decaying vegetable matters yield the water a large supply of carbonic acid. On the other hand, a mechanical waste is also very generally taking place to a greater or less extent: and thus numerous rivers are continually cutting back their beds, and forming ravines. The Falls of the Niagara River have in this manner gradually receded from the face of the escarpment near Queenston to their present site; and there is scareely a river, or small stream indeed, in any part of Canada, that does not exhibit indications of having occupied at one period a wider bed and higher level than at present. This erosive power of rivers has probably been assisted in many instances by a gradual elevation of the surrounding land. Some of the grandest examples of river erosion are exhibited by the canons of the Colorado and other streams west of the Rocky Mountains. In some of these remarkable ravines, the stream

SEDIMENTARY ROCKS.

has excavated its channel, within almost perpendicular walls of limestone and other rock, to a depth of a thousand feet or more.

The amount of detrital matters borne down by some rivers to the sea, is exceedingly abundant. This is well shown by the formation of deltas. The delta of the Mississippi on this continent, for example, like all other deltas, is derived essentially from the sandy and other matters brought down by the stream. On entering the sea, the velocity of the river is necessarily checked, and the sediments are thus thrown down. Much of the coarser matter is indeed deposited on the bed of the river itself, raising this, and compelling the formation of artificial banks, or levées, to prevent inundations. Finally, as' a well-known illustration of the immense amount of sedimentary matters borne seawards by certain rivers, the case of the Ganges, as described so fully by Sir Charles Lyell, in his "Principles of Geology," may be hero cited. That river, it has been demonstrated by actual observation and experiment, conveys annually to the sea an amount of matter that would outweigh sixty solid pyramids of granite, supposing each, like the largest of the Egyptian pyramids, to cover eleven acres at its base, and to stand 500 feet in height. The delta of the Ganges, composed of mud, &e., thus brought down by the river, extends for 200 miles along the coast, and commences far inland.

A considerable quantity of sediment is also produced by the slow <u>movements of glaciers</u> in Alpine and other districts in which these remarkable ice-rivers prevail. The glacier of the Aar, which covers with its tributaries an area of only six or seven square miles, thus furnishes daily, according to some recent researches of M. Collomb, at least 100 cubic yards of sand. This is carried off by its terminal stream or torrent.

Action of the Sea (and of large bodies of Water generally).—Vast in amount as are the sediments collected by rivers, they are far surpassed by the accumulation of detrital matters obtained by the waves and breakers of the sea. All who have resided for any length of time on an exposed and rocky coast, must be well aware of the destructive action of the waves. The cliffs subjected to this action, gradually become undermined and hollowed out; and thus large masses of rock are brought down by their own weight. These, sooner or later, are broken up, and spread in the form of sediment along the shore, or over the sea-bottom. On some coasts, the amount of land destroyed in this

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manner almost exceeds belief.* On some parts of the eastern shores of England, and the opposite or western shores of France, for example, the sea has thus carried off, within the present century, from fifty to over two hundred yards of coast--measured backwards from the shoreline-along a distance of many miles. Grave-yards, shewn by maps of no ancient date to have been located at considerable distances from the sea, have become exposed upon the cliff-face; and forts erected by the First Napoleon on the French coast, at two hundred metres and upwards from the edge of the cliff, now lie in ruins on the beach, or have altogether disappeared. These localities are mentioned as being more especially known to the writer; but in all parts of the world examples may be found of the same destructive process. In the clay and sandy bluffs of our own lakes, as at Scarboro' Heights on Lake Ontario, and elsewhere, effects of this kind may be equally studied.

Confining our view at present to these results only, it must be evident to all that an enormous amount of sedimentary matter is annually, or even daily, under process of accumulation. The question then arises as to what becomes of this. The reply is obvious. The detrital matter thus obtained, is deposited in lakes or at river-mouths, or along the sea-shore, or over the sea-bed—contributing day by day to the formation of new rocks. In other words, existing rock-masses, worn down by atmospheric agencies, by streams and rivers, and by the action of the sea, supply the materials for other and, of course, newer rock deposits. And thus, when we look upon a piece of stone derived from one of these, we may picture to ourselves the scene of its formation, and, with the poet, hear—

"The moaning of the homeless sea,

The sound of streams that swift or slow Draw down Zeonian hills, and sow The dust of continents to be—"

for truly, is it the dust of new continents that is thus being deposited, atom by atom, by these slow but continued processes.

<u>Deposition of Sediments.</u>—All sediments diffused through deep or quiet water, arrange themselves, under general conditions, in horizontal

^{*} It would obviously be out of place m an Essay like the present, to enlarge on this point. The reader unfamiliar with geological details of this character, should consult, more especially, Lyeli's *Principles of Geology*, and also the *Cours Elémentaire* of the late Aleida d'Orbigny.

SEDIMENTARY ROCKS.

or nearly horizontal beds: the latter, if deposited on gently-sloping shores. Professor H. D. Rogers, in his Report on the Geology of Pennsylvania, contests to some extent this usually-received view, and maintains that certain inclined strata of mechanical formation were originally of inclined deposition. This may be true under local or exceptional, but certainly not under general, conditions. (See proofs, further on.) Where, however, sands and gravels are thrown down by currents and running streams, an oblique arrangement commonly takes place; but this is more or less confined to the subordinate layers of which the larger beds consist, as shewn in the annexed figure. The

inclined layers have sometimes different degrees of inclination, and even dip (in different beds of the same strata) in opposite directions, indicating changes in the tidal or other currents by which they were thrown down. This inclined arrangement is termed "false bedding," or "oblique stratifica-

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tion." It may be seen in some of the ancient, and also in some of the more modern deposits of this continent, as in the Chazy Sandstone of the south shore of Lake Superior, and in the Drift gravels of many parts of Canada.

<u>Consolidation of Sediments.</u>—Having thus rapidly traced out the formation of the mechanically-formed sedimentary rocks up to their deposition in the state of detrital matter on the beds of seas, lakes, or estuaries, we have now to inquire how these accumulations of mud, sand, &c., become hardened into rock, properly so-called.

Most sediments hold within themselves the elements of their own consolidation, in the form of particles of calcarcous or ferruginous matter, which act upon the other substances in the manner of a cement, causing the whole to "set" or harden under water. Frequently, also, a large amount of calcarcous matter is derived from the decomposition or solution of imbedded shells and other organic remains made up of carbonate of lime. In the majority of strata, and in sandstones more especially, merely easts or impressions are thus left, in place of the originally imbedded shells. Masses of solid conglomerate are daily under process of formation, in places where springs containing calcareous or ferruginous matters infiltrate through the gravels and pebblebeds of our Drift deposits. Many thermal springs (as well as many river-waters) also contain considerable quantities of silica in solution; and there is reason to believe that in former periods of the Earth's history, springs of this kind must have prevailed to a very great extent. These, flowing into seas and lakes where sediments were under process of deposition, must also have lent their agency towards the consolidation of such deposits. Many of our Canadian limestones, it may be observed, are more or less siliceous.

The enormous pressure exerted upon low-lying sedimentary beds by masses of superincumbent strata, must likewise have been sufficient in many instances to have effected consolidation.

The heat transmitted in earlier periods from subterranean depths, or generated amongst low-lying sediments by chemical action, may also have been concerned in the work of consolidating the originally loose materials of stratified rocks. It may be remarked, likewise, that sediments occasionally become solidified by simple desication. The shellmarl, or calearcous tufa, of our swamps, &c., becomes thus hardened on exposure to the air.

SUBSEQUENT ACTION OF NATURAL FORCES ON SEDIMENTARY ROCKS.

The more important effects produced on sedimentary rocks, from the period of aggregation, are as follows:—(a) Elevation above the waterlevel, with Alternations of Upheaval and Depression; (b) Denudation; (c) Tilting up and Fracturing; (d) Metamorphism. It is of course to be understood, that whilst certain strata may have experienced all of these effects, others may have been subjected to upheaval, or to upheaval accompanied by denudation, only.

(a) <u>Elevation above the Sea Level</u>: — The stratified rocks, it has been shown, must have been deposited originally, in the form of sediments, under water; and from the marine remains which so many of these rocks contain, it is evident, that, as a general rule, they were laⁱ down on the bed of the sea, either in deep or in shallow water these rocks, however, now, at various heights above the sea. . , and frequently far inland. Hence of two things, one: either the sea must have gone down, or the land must have been elevated above the water

The sinking of the sea would appear at first thought to be the more rational explanation of this phenomenon; but if we look to existing Nature, we find no instance of the recession of the sea, unaccompanied, at least, by an elevation of the adjoining coast or sea-bottom, whilst we have many well-proved examples of the actual rising and sinking of the land. In connection with this inquiry, it must be borne

SEDIMENTARY ROCKS.

in mind that the sen cannot go down or change its level at one place without doing the same generally all over the world.

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To afford a few brief illustrations, it may be observed that on several occasions within the present century, large portions of the Pacific coast of South America have been raised bodily above the sea, leaving beds of oysters, mussels, &c., exposed above high-water mark. The phenomenon, to the inhabitants of the coast, appeared naturally to be due rather to a sinking of the waters than to an actual elevation of the land; but at a certain distance north and south of the raised districts, the relative levels of land and sea remain practically unaltered : and hence, if the sea had gone down within the intervening space, to the extent indicated, its surface must have presented an outline of this character $f(x) = \frac{1}{2} + \frac{1}{2}$

The land is also known to be slowly rising and sinking in countries far removed from centres of volcanic activity. Careful observations have shown, for example, that the northern parts of Sweden and Finland are slowly rising, and the south and south-eastern shores of the Scandinavian peninsular are slowly sinking : whilst around Stockholm there is no apparent change in the levels of land and sea. The whole of the western coast of Greenland is inferred to be slowly sinking : buildings erected on the shore by early missionaries, being now in places under water. A slow movement of depression is likewise taking place along the shores of Cape Breton and Nova Scotia generally; and, probably also, to some extent, on the Atlantic sea-board of the United States. On the shores of Newfoundland, of Cornwall, and other districts. examples occur of sub-marine forests, or of the remains of modern trees, in their normal positions of growth, below low-water mark; whilst in neighbouring localities no change of level appears to have taken place. Besides which, without extending these inquiries further, we know that many fossiliferous strata are hundreds, and even thousands, of feet above the present sea-level. On the top of the Collingwood escarpment, for example, we find strata containing marine fossils at an elevation of over 1500 feet above the sea; and on the Montreal mountain, shells of existing species occur at an elevation of about 500 feet. Hence, if these strata had been left dry land by the sinking of the oceanic waters in which they were deposited, an immense body of water, extending over the whole globe, must in some unaccountable manner have been caused wholly to disappear. It is therefore now universally admitted, that the sedimentary rocks, as a rule, have come

into their present positions, not by the sinking and retiring of the sea, but by the actual elevation of the land.

Many strata afford proofs of having been clevated and depressed above and beneath the sea, successively, at different intervals. Many sandstones, for example, exhibit ripple-marked surfaces, and occasionally impressions of reptilian and other tracks, throughout their entire thickness. This indicates plainly that they were formed slowly in shallow water, and that they were left dry, or nearly so, between the tides. And it indicates, further, that the shore on which they were deposited layer by layer, was undergoing a slow and continual movement of depression : otherwise the process of formation would necessarily have ceased, and the strata would present a thickness of a few inches only, or of a few feet at most. Afterwards a period of upheaval must have commenced, bringing up the rocks to their present level. In certain strata, also, the upright stems of fossil trees occur at various levels; and in some localities, beds containing marine fossils are overlaid by others holding lacustrine or fresh-water species; and these again by others with marine remains. Finally, to bring this section to a close, we have a striking example of alternations of land-upheaval and depression in the geology of Canada generally. Around Toronto, for example, we have certain strata of old date, belonging to the Lower Silurian Series, overlaid by deposits of clay, gravel, and sand of the Drift Epoch, a comparatively modern period. Between the two, a vast break in the geological scale occurs. Many intervening formations, indicating the lapse of long periods of time, are present in other parts of this continent; and hence, it is concluded that the Silurian deposits of this locality, after their elev ion above the sea, remained dry land for many ages, whilst the intervening groups were under process of deposition in other spots; and that, finally, at the commencement of the Drift Period, the country was again depressed beneath the ocean, and covered with the clays, sands, and boulders of this latter time. Another period of elevation must then have succeeded, bringing up both the Silurian and the Drift formations to their present levels above the sea.

(b) <u>Denudation</u>:—This term, in its geological employment, signifies the removal or partial removal of rock masses by the agency of water. The abrading action of the sea, of rivers, &e., acting under ordinary conditions, has already been alluded to; but the erosive effects of water may be seen in numerous localities in which this action is no longer in force. Sections of the kind shewn in the accompanying

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FIG. 85,

lating or rolling countries. Here it is evident that the strata were once continuous in the space be-

tween A and B. Valleys which thus result from the removal of strata, are termed "valleys of denudation." Some of these valleys are many miles in breadth. Their excavation, consequently, could not, in the majority of instances, have been effected by atmospheric agencies, or by the streams which may now occupy their lower levels; but must have been caused essentially by the denuding action of the sea during the gradual uprise of the land, or during alternate movements of elevation and depression, in former geological epochs. If the bed of the Atlantic, for example, were now being raised from beneath, at the rate of a few inches in a year or series of years, an enormous valley would probably be scooped out along the course of the Gulf Stream; and in other places where currents prevail, more or less continuous valleys would also be formed. Isolated patches of strata have been frequently left by denudation at wide distances from the rocks of which they originally formed part. These are termed "outliers." Thus in Western Canada, small isolated areas, occupied by bituminous shales of the Devonian series, occur in the townships of Bosanquet and Warwick, and constitute outliers or outlying portions of the Chemung and Port. age group (see Part V), largely developed in the adjoining peninsula of Michigan. The matter carried off in some districts by denudation, must have been of enormous amount; and when it is considered that most of the inequalities on the Earth's surface-those at least not immediately connected with mountain chains-have been thus produced, the part played by the denuding agencies of former periods in providing the materials of newer strata, may be readily appreciated.

(e) Tilting up and Fracturing of Strata.-Whilst some strata retain their original horizontality, others are more or less inclined, and some few occupy a vertical and even a recurved position. That strata were not originally inclined, at least to any extent, is proved by the known arrangement of sediments when diffused through water,-these (with the exceptional cases already pointed out) always depositing themselves in horizontal, or nearly horizontal, layers. The same fact

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is shewn also by the frequent presence of rows of pebbles, fossil shells, &c., parallel with the planes of stratification, as in Fig. 86; by the occasional presence of the fossilized stems of trees (evidently in their positions of growth) standing at right angles to these planes (Fig. 87); and sometimes by the presence of stalactites suspended in a similar position. It is evident that these bodies could not have been originally inclined in this manner to the horizon.

The inclination of strata is technically termed the dip; and the direction of the up-turned edges, the strike. The dip and strike are always at right angles. In observing the dip, we have to notice both its angle or amount, and its direction, or bearing—as north, north-east, N 10° E, and so forth. The direction of the dip is of course ascertained by the compass; the rate of inclination, by the eye, or by an instrument called a clinometer. The most convenient instrument for both purposes, is a pocket compass, set in a square bed, or attached to a square plate of metal, and furnished, in addition to the needle and graduated limb, with a moveable index. The latter hangs freely from the centre of the compass, and plays round a graduated are, as in the

annexed figure. When the upper edge of the compass is held horizontally, the index cuts the zero point of the graduated are. From each side of this point, the graduation is carried up to 90°. If, consequently, the upper edge of the instrument be placed paratlel with the inclined beds of any strata, the angle of the dip will be at once shewn by the index. A contrivance of this kind, exclusive of the compass, may be easily made out of a semicircle



FIG. 83.

of hard wood. The index may consist of a piece of twine extending below the graduated limb, and kept taut by a lead plumb or by a stone.

In a compass used for taking bearings, it is convenient to mark the west side EAST, and the cast side WEST, as in the figure. If the north side of the instrument be then kept always in advance, and the angle be always taken from the north end of the needle—no matter what the actual direction of the line—the true magnetic bearing is obtained at once, and without risk of error. The compass is most readily held by passing the thumb through a short strap or loop, or through a hinged ring, attached to the under side of the box. Where very accurate bearings are required, sights may be used, the instrument being fixed on a support; or a prismatic compass may be more conveniently employed.

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When strata dip in two directions, as at A, in Fig. 89, the line along the culminating point of the strata is termed an <u>Anticlinal</u> or <u>Anticlinal Axis</u>; and the line from which the strata rise in opposite directions, as at S in the figure, is called a <u>Synclinal</u> or <u>Synclinal Axis</u>. Synclinals when of a certain magnitude, constitute "valleys of undulation." Anticlinals are also often hollowed out by denudation, forming valleys or troughs called "valleys of clevation," as shewn at E in Fig. 89. The term "elevation" applies here, it should be observed, to the raised strata, and not to the actual position of the valley, as many of these so-called valleys of elevation lie in the beds of rivers, or occupy comparatively low ground. The River Humber near Toronto, for example, flows at the lower part of its course over a denuded anticlinal of this character.* Finally, it may be observed, that when strata lie in parallel beds (as in Figs. 85 and 89), the stratification is said to be conform



* Professor Robert Bell in his Report on the Manitoulin Islands, has pointed out the occurrence of fifteen anticlinals, crossing the Great Manitoulin in a general north and south direction. These anticlinals give rise on the north shore of the island to deep indentations or bays, and inland to a series of parallel lakes.

able or concordant. When on the other hand, the beds are not parallel, the stratification is said to be <u>uncomformable</u>. The accompanying sec-



commencement of a new geological period.

tion, in which the inclined beds belong to the Laurentian, and the overlying beds to the Lower Silurian Series (see Part V), as shewn on Crow Lake, north of Marmora village, is an example of unconformable stratification, or of want of concordance between these two series of rocks. As explained further on, a want of conformability indicates almost invariably the

Both horizontal and inclined strata frequently exhibit fractures of greater or less extent. Mineral veins, it may be mentioned, consist essentially of eracks or fractures formed at some more or less remote period in the surrounding rocks, and filled subsequently by various agencies, with sparry, earthy, and metallic matters. The strata on one side of a fracture are often displaced, being thrown up or down as it were. This peculiarity is technically termed a *fuult*. The levels

occupied by a displaced bed are sometimes only a few inches, and at other times upwards of a thousand feet, apart. At the first formation of a fault or slip, an escarpment or terrace of greater or less height must necessarily have been produced; but in very few cases (if in any case unconnected with existing carthquake phenomena) is anything of this kind now ob-



servable, the ground having been levelled down at some after period by the agency of denudation. In mountainous districts the fracturing of strata has sometimes given rise to narrow gorges or so-called "valleys of dislocation," but most of these have been subsequently enlarged by the atmospheric disintegration of the surrounding rocks, and by the streams or torrents of which they usually form the channels.

(d) <u>Metamorphism</u> : — Many strata afford undeniable proofs of having been greatly altered, as regards texture and other mineral

SEDIMENTARY ROCKS.

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characters, from their original sedimentary condition. In many instances, indeed, the original composition of the rock appears to have been changed. Strata thus affected, are commonly known as metamorphic or altered rocks. In some cases a passage can be traced from the altered into the unaltered parts of the rock; but, frequently, where rocks have been subjected to this action, the alteration has extended over wide areas, and has been more or less complete. It consists most commonly in the assumption of a crystalline structure, and is very generally accompanied by the presence of crystallized minerals and other indications of chemical action.

In numerous instances, metamorphism, on a limited scale, has evidently resulted from the direct intrusion of eruptive rock matters amongst sedimentary formations. Where trap dykes or masses of granite, for example, have been thrust up through fissures in ordinary strata, the latter are seen in many cases to have been more or less altered around the points of contact, as though by the agency of intense heat, or by that of steam or other gases acting under pressure. Coal has been thus converted, within a certain distance of interpenetrating trap masses, into cinder and coke; earthy limestone, into crystalline marble; sandstone into quartz rock, and so forth; and somewhat analogous effects are occasionally produced in sandstone blocks that have been long exposed to heat and heated vapours in the interior of certain furnaces. These effects however, have not always followed the intrusion of eruptive rocks; and in no case do they appear to have extended far into the mass of the surrounding strata. The alteration of extensive regions therefore, such as the wide area occupied by the Laurentian strata of Canada (see Part V), points evidently to some more general although probably related cause, in explanation of the facts of metamorphism. Whatever view be adopted respecting the internal condition of the earth, it is clear that immense spaces filled or partially filled with molten and vaporous matter must have existed through untold ages at certain depths beneath the surface rocks; and the chemical action going on within these spaces, and emanating from them, may be regarded as sufficient to produce the results in question, even if we cannot explain, to our thorough satisfaction, the actual processes involved in the production of these effects. See further under the METAMORPHIC ROCKS described below.

A special effect of metamorphism, developed more particularly in finegrained argillaceous strata, is the production of *slaty cleavage*. Rocks

thus affected, exhibit a more or less strongly-pronounced fissile texture, arising from the presence of numerous divisional planes running parallel with one another through the rock, and usually in a direction inclined to that of the planes of deposition. It is not always easy, in inclined strata, to distinguish the latter planes from planes of cleavage; but their direction is generally revealed by the presence of fossils, or by intercalated layers of a different shade of colour, degree of fineness, &c., across which the cleavage lines commonly pass without interruption. Cleavage in rocks, as shown by this latter condition, and by the fact that fossil bodies and imbedded stones are frequently drawn out or unnaturally clongated in the direction of the cleavage planes, is evidently a superinduced effect; but much obscurity still prevails with regard to its actual origin. It is usually attributed to mechanical pressure acting laterally upon the rock during elevations or depressions of contiguous areas; but it may be really due to the effect of long continued heat on confined masses of damp strata. Moist elay, for example, if exposed in a covered vessel to a certain degree of furnace heat, almost invariably assumes a fissile texture; and the same peculiarity is observable in biscuits that have undergone an extra firing for ships' use. Oblique cleavage is exhibited by many of the clay-slates of the Eastern Townships, as those of Melbourne, Cleveland, Kingsey, &c.; but the clay slates of Lake Superior and other parts of the province, though more or less finely laminated, appear to be entirely destitute of true cleavage planes of this character.

III. METAMORPHIC OR CRYSTALLINE STRATIFORM ROCKS.

The rocks of this series are stratified rocks of a more or less crystalline aspect. In their mineral characters they frequently bear a great resemblance to cruptive rocks, to which indeed they are closely allied —almost every metamorphic rock having its representative in the eruptive series; but they differ from these latter by their general conditions of occurrence. As explained above, many sedimentary strata are seen to have assumed a crystalline texture, or to have lost more or less completely their normal sedimentary aspect, in the vicinity of intrusive masses of granite, greenstone, or other eruptive rocks. An alteration of this kind is known as local metamorphism. Earthy or ordinary limestones and dolomites are thus occasionally converted into

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hard crystalline marble, often veined with green and other coloured streaks and patches of serpentine, and filled in many cases with crystals or crystalline particles of graphite, pyroxene, amphibole, various micas, tourmaline, garnets, pyrites, and other minerals, foreign to the rock in its sedimentary condition. In like manner, sandstones are changed in colour and texture, and are often converted into quartz-rock or some variety of gneiss; and clay-slates are transformed into mica-slate, taleslate, hornblende-rock, and other so-called crystalline schists and gneissoid aggregations. These metamorphic results are probably due in part to the agency of various gases and heated vapours which accompanied the protrusion of the eruptive mass. Alterations of a similar kind, but extending over wide areas, are seen, on the other hand, to have taken place in many localities, without the direct intervention of eruptive rocks. This widely extended metamorphism has probably been effected by alkaline and other solutions acting on the heated rocks, or by the agency of superheated steam and other vapours on deeply-scated strata, or by other causes more or less immediately connected with the presence of subterranean heat. In many cases there can be no question as to these crystalline strata being really altered sedimentary deposits, and thus, by inference, a similar origin is generally attributed to all rocks of this character. Whilst sedimentary rocks, proper, are the products of surface action, and eruptive rocks-as regards their present condition, if not in all cases their actual origin-are products of internal or subterranean forces, metamorphic formations may be regarded as the result of both external and internal agencies.

The metamorphic rocks of Canada belong, as regards their geological age, to two distinct series. The older series, of Eozoic age, comprises the rock formations of the Laurentian and Huronian periods, and occupies all the more northern and north-western portions of Quebee and Ontario, its strata consisting chiefly of enormous beds of gneiss, erystalline limestone, siliceous slates, and other rocks, enumerated below, and described fully in Part V. The higher or less ancient series is of <u>Pakeozoic age</u>, and belongs chiefly to the <u>Silurian period</u>. Its strata occur in patches on Lake Superior, but are chiefly developed in the form of chloritic and talcose slates and beds of serpentine, throughout the Eastern Townships and adjoining region south of the St. Lawrence, in the Province of Quebee.

The following are the more important metamorphic rocks of Canadian | occurrence :---

Gneiss :- This rock is made up normally of three minerals-quartz, feldspar, and mica : the two latter being generally the common potash species, orthoclase and muscovite (See PART I). In coarsely crystalline varicties of the rock, these minerals are easily recognized. The feldspar is usually light grey, or red, and present in distinctly cleavable grains or masses; the mica in leafy masses or small scales of a silvery white, brown, or black colour; and the quartz in colourless vitreous grains. The striped or banded aspect of the rock generally serves to distinguish it, in hand specimens, from granite; and when seen in Nature, its stratified structure is in most cases very apparent. Vast beds of gneiss, and strata of gneissoid rock in which the component minerals are more or less indistinct, occur throughout the wide area occupied by the Laurentian rocks of the more northern regions of Canada (See Part V), and also here and there, in the less ancient metamorphic district south of the St. Lawrence. Most of the boulders, scattered so abundantly over the surface of Canada, consist of mieaceous gneiss, or of the hornblendic variety described below. In some localities the mica of ordinary gneiss is partially replaced by scales of graphite.

<u>Syenitic or Hornblendic Gneiss</u>: — This rock only differs from ordinary gneiss by containing hornblende in place of mica; but the two rocks frequently merge into one another, both hornblende and mica being present in certain varieties. Normally, the hornblendic variety of gneiss is composed of red or grey feldspar, with quartz, and black or green hornblende. The three minerals are sometimes vory distinct; but in other cases they are intimately blended, so as to form a dark green rock, which passes, by the gradual diminution of the quartz, into hornblende-slate or amphibolite. Syenitic gneiss occurs abundantly, with ordinary or micaceous gneiss, in the Laurentian districts of Canada (See Part V).

<u>Mica Slate</u>:—This is a foliated or schistose rock, composed essentially of quartz and mica. It is generally of a grey, greyish-green, or silvery-white colour; but is sometimes black and highly lustrous from the presence of intermixed graphite, as in many parts of the "Eastern Townships" of Quebee. It passes into clay-slate, and also into finegrained gneiss and other rocks of the metamorphic series. Mica-slate occurs here and there throughout the Laurentian area of Canada, and in the altered districts south of the St. Lawrence (See Part V); but characteristic examples are rare—the rocks in question being rather micaceous slates than mica-slate as commonly defined.

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Anorthosite or Feldspar-Rock : - This rock, to which the term "anorthosite" was first applied by Dr. Sterry Hunt, is composed essentially of lime or soda feldspar, or of a mixture of various Trielinic feldspars, species distinguished from the common potash type Orthoclase, by the oblique meeting of all their cleavage planes, and very generally also by the presence of a delicate striation on some of these planes. The colour of feldspathic rocks of this kind is mostly some shade of grey, greenish-white, or lavender-blue; but some are pale red or yellowish-white; and the planes of cleavage occasionally exhibit the green or greenish-blue reflected tints characteristic of Labradorite. All become opaque-white by weathering. The stratified structure is often more or less obscure. Feldspathic rocks of this character occur largely in the upper part of the Laurentian series (forming the division lately separated under the name of the Labrador Formation) in the counties of Argenteuil, Terrebonne, and Montmorency, in the Province of Quebec. Dr. Sterry Hunt has indicated the occurrence of beds of similar composition in the township of Potton, among the less ancient inetamorphic strata south of the St. Lawrence.

Hyperite or *Hypersthene-Rock*:—This is simply a variety of feldspar rock containing laminar or foliated masses of bronze-coloured or dark-green hypersthene. Examples occur at Château Richer in Montmorency County, and elsewhere, among the anorthosites described above.

<u>Pyroxenite</u> or <u>Augite-Rock</u>:—This rock, of subordinate occurrence, consists at times of almost pure augite or pyroxene, but in general it forms a granular compound of augite and some kind of feldspar, more or less intermixed with earbonate of lime. Frequently also it contains ehlorite, with grains of magnetic iron ore and other minerals. The normal colour is dark green. Examples occur here and there in connection with the beds of crystalline limestone and iron ores of the Laurentian Formation, as at Calumet Falls on the Ottawa, and parts of Madoc and Marmora. In many cases pyroxenite cannot be distinguished from hornblende rock; and it closely resembles in general character and composition many cruptive masses and dykes belonging to the trappean series.

Amphibolite or Hornblende Rock:—This metamorphic product is sometimes described as diorite, but the latter term is properly restricted to eruptive greenstones of similar composition. Hornblende Rock is

composed normally of a mixture of hernblende and soda-feldspar, but at times it consists of almost pure hornblende. Many varieties are also more or less calcarcous, and in some, both mica and quartz are occasionally present. These pass into sygnific gneiss. The texture of the rock is compact, granular, fibrous, or slaty. The slaty varieties are commonly known as Hornblende Schist, and the fibrous as Actynolite Rock or Schist. Examples occur in some abundance among the Laurentian strata of Marmora, Madoc, Elzevir, Blythfield, and throughout the Laurentian country generally between the Ottawa and Lake Huron, also at various places on Lake Surgevior, as at Point-aux-Mines, Goulais River, and elsewhere. Hornblendic rocks and slates form part also of the altered Silurian deposits of Beauce and other districts of the Eastern Townships.

Wollastonite-Rock :- The mineral Wollastonite (No. 64, Part II), mixed with feldspar, pyroxene, quartz, caleite, and other minerals, occasionally forms beds in the Laurentian series, mostly in association with crystalline limestone. Where the Wollastonite predominates, the rock presents a granular-fibrous structure, and is white or pale-greenish in colour. Examples occur in the counties of Argenteuil, Terrebonne, Leeds, &e., but are comparatively unimportant.

Epidote-Rock :— This is also of subordinate occurrence. It consists of a mixture of quartz and epidote, and presents both granular and compact varieties, mostly of a pale-green colour. Examples have been recognized amongst the altered strata of the Shickshock Mountains of Gaspć, and others occur in Melbourne and other parts of the Eastern Townships.

Garnet-Rock :--Subordinate beds of this rock, composed essentially of granular red garnets and crystalline quariz, occur among the Laurentian strata of St. Jérome on the Ottawa, and Rawdon in Montcalm county; and also, according to Mr. Richardson, in association with micaccous schists at Baie St. Paul. Dr. Sterry Hunt has likewise made known the occurrence of beds of more or less compact and lightcoloured garnet amongst the metamorphic series of the Eastern Townships. See under "Garnet," in Part II.

Quartzite or Quartz Rock :---This rock consists normally of pure crystalline quartz, either colourless, or of pale shades of red, yellow, green, or smoky-brown. Coarse and more or less opaque varieties, passing into quartzose sandstone and chert, exhibit various colours,

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however; and the rock is often green and greenish-grey from admixture with chlorite. Some cherts are black from the presence of anthracitic matter. Enormous beds of quartzite, frequently very pure, occur in the Lanrentian series of strata, as on the River Rouge in the county of Argenteuil, and elsewhere; and these rocks are still more characteristic of the Huronian strata. Laurentian quartzose conglomerates occur in the townships of Bastard and Rawdon; and a very remarkable conglomerate of the Huronian series, consisting of pebbles of colorless quartz and red jasper in a colorless, greenish-white, or pale-yellowish quartzose base, is met with in the Bruce Mines district. These crystalline conglomerates show unmistakably the metamorphic origin of the rock. Beds of chert and jaspery quartz occur also in the higher metamorphic series of Lake Superior, and in the altered region south of the St. Lawrence (see Part V).

Siliccous State:—This rock is probably an altered elay-state. It passes into impure quartz rock or jasper; consists essentially of a silicate of alumina; is hard and more or less slaty, and usually of a greenish-grey colour, or dark green from intermixed chlorite, and oceasionally striped or zoned with lines of black, green, or red. Examples of siliceous slates are of common occurrence on the north shore of Lake Huron, and amongst the Huronian strata of the River Doré and other localities on Lake Superior. In many places, these slates hold rounded pebbles or masses of gneiss, syenite, &c., and thus form "slate conglomerates."

Argillite :— This is one of the least altered rocks of the metamorphic series. It is simply a more or less inducated clay-slate, and commonly presents a black or blueish-black or dark-grey colour, but some varieties are dull chocolate-red, and others greenish-grey,— the rock passing by insensible transitions into ordinary unaltered shales on the one hand, and into siliceous and micaceous slates on the other. Many argillites contain small straw-like erystals of chiastolite or andalusite, as described under that mineral in Part II. Dark and more or less lustrous varieties are common in Huronian strata, and are still more abundant in the higher metamorphic series of Thunder Bay, Lake Superior (see Part V), and in various parts of the altered region south of the St. Lawrence. In the latter district, as in Beauce and elsewhere, many of the green, purplish, and red argillites present a nacroous talcose aspect, but, as shewn by Dr. Hunt's analyses, they contain little or no magnesia.

Chlorite Slate :- This metamorphic rock in its normal aspect is a compound of chlorite and quartz, possessing a distinct green colour and a foliated or schistose structure. In Canada, chlorite slates, passing into chloritic strata in which the typical character of the rock is more or less obscured, occur sparingly in the Laurentian series, in connection with the iron ores of Madoe and Marmora. A bed of a dark green colour, filled with numerous small octahedrons of magnetic iron ore, occurs likewise in the township of Galway. Other examples, but of somewhat obscure character, form part of the Huronian rock series, as at Thessalon point, and elsewhere. In the altered Silurian region south of the St. Lawrence, chloritic slates on the other hand are especially abundant, and most of the copper ores of the Eastern Townships are associated with these strata. Other beds contain intercalated scales and layers of specular or micaceous iron ore; and in the Townships of Bolton and Broughton, more or less compact or subfoliated beds of greenish-grey chlorite form workable beds of good quality. (See Part II, No. 80.)

Steatite or Soapstone-Rock :— This rock consists of granular or slaty tale, frequently intermingled with carbonate of lime or dolomite. It usually presents a greyish or greenish-white colour, and when pure is very sectile. A bed of somewhat inferior quality, from intermixture with calcareous matter, occurs in the Laurentian strata of Elzevir. The closely related substance known as Pyrallolite (see under No. 82, in Part II), also forms beds among the Laurentian series of strata, as in Grenville, Ramsay, and elsewhere. Many deposits of more or less compact soapstone occur likewise in the higher metamorphic series of the Eastern Townships, as in various parts of Bolton more especially, and also in Potton, Sutton, Stanstead, Leeds, and Vaudreuil.

Ophiolite or Serpentine Rock :—This rock consists essentially of the hydrated magnesian silicate, Serpentine, described fully in Part II. It usually presents a green, brown, greenish-grey, or pale yellowish colour, often veined or mottled with lines and patches of darker or lighter green, red, or reddish brown; and it forms more or less compact beds, frequently of great extent and thickness. Subordinate examples occur in the Laurentian strata of many localities, mostly associated with bands of crystalline limestone, as in the township of Grenville, and at Calumet Island on the Ottawa; also in Burgess, and elsewhere; but the altered Silurian districts south of the St. Lawrence

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contain the most abundant and important deposits of serpentine rock, as at Mount Albert in Gaspé, and in the Eastern Townships of Melbourne, Oxford, Broughton, Bolton, Ham, and Garthby, more especially. The serpentine of these districts is very commonly associated with beds of chromic iron ore; and many examples are intermixed with crystalline calcite or dolomite, forming ornamental "serpentine-marbles" of green, chocolate-brown and other colours.

Crystalline Limestone:-This rock consists of carbonate of lime in a crystalline or semi-crystalline condition. It is usually white, light grey, or pale reddish, in colour, and is sometimes veined or spotted with yellow, green, blueish-grey and other tints. It presents most commonly a fine or coarse granular structure, much resembling that of loaf sugar, whence the name "saccharoidal limestone" by which this rock is often known; but some varieties are more or less compact; and others present in places a fibrous aspect, from intermingled tremolito or white hornblende. The finer kinds form the ordinary marbles of commerce. In Canada, large beds of crystalline limestone, often containing scales of graphite, and crystals of apatite, pyroxene, amphibole, mica and other minerals, occur among the Laurentian and Huronian series of strata in numerous localities (See Part V); and also among the altered Silurian strata south of the St. Lawrence. In the latter district, as already mentioned, some of these limestone beds are intermixed with green and other coloured serpentines, but many of the so-called serpentine marbles from the Eastern Townships are mixtures of serpentine with dolomite or magnesite.

Crystalline Dolomite :—This rock resembles crystalline limestone in colcur and other external characters, but consists of carbonate of lime and carbonate of magnesia, and only effervesces when tested with heated acid (See Part I). It occurs, here and there, amongst the Laurentian strata, as at Lake Mazinaw in the County of Frontenae, and elsewhere. Also among the altered Silurian strata of the Eastern Townships, in which district beds of crystalline magnesite (See Part II), mixed with mica, scrpentine, &c., are likewise present. Theso magnesian beds, as pointed out by Dr. Sterry Hunt, assume a yellowish or dull-red colour by weathering.

Crystalline Iron Ores :---Vast beds of Magnetic, Specular and Titaniferous Iron Ore, occur locally amongst the rocks of the Laurentian series, and should thus be referred to in connexion with the metamor-
phic formations of Canada. The altered strata of the metamorphic region south of the St. Lawrence are also especially characterised in certain localities by the presence of chromic iron ore in rock masses; and many of the chloritic and other schistose strata of this region pass locally into "iron slates" or "specular schists," by the addition of micaccous hematite or specular ore. The distinctive characters of these Iron Gres, and their principal localities, are given in Part II. Their geological relations come under review in Part V.

IV. ERUPTIVE OR UNSTRATIFIED ROCKS.

The rocks of this division are commonly known as *Igneous Rocks*. With regard to the igneous formation of certain members of the Eruptive Series, there can be no possible doubt; but the actual mode of formation of other rocks of this group is involved in great obscurity. All agree however in being essentially devoid of true planes of stratification. They occur either in irregular unstratified masses; or in sheets or apparent beds, intercalated amongst, or overflowing, stratified deposits; or in the form of more or less tortuous veins; or in <u>broader</u> and <u>simpler veins</u>, technically known as "dykes," which frequently terminate at their upper extremity in overlying step-like and columnar sheets of matter. And in these conditions, they are frequently scen to traverse older rocks of the same class, or to penetrate various stratified formations. They are thus essentially *intrusice rocks*; and they are

also, in the words of Humboldt, essentially <u>endogenous</u> rocks — *i. e.* they come from more or less deeply-seated sources within or beneath the Earth's erust, from whence they have been



F16, 92,

forced up from time to time through cracks and fissures opened in the overlying or surrounding rock masses. From this it follows, as a general rule, that the intrusive rocks in question must have been at one time in a soft and plastic state, if not in an actually fluid condition. Certain trachytic and basaltic rocks—members of this group,

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described below—cannot be distinguished by chemical or mineralogical characters from ordinary lavas; and the former existence of many basalts in a molten or highly heated condition is established by the effects produced by veins or dykes of these rocks on coal beds and other strata through which they have been erupted. Coal in contact with dykes of this kind, has been burnt into cinder, or converted into coke; clays have been baked into brick-like masses; sandstones rendered more or less vitreous; and various limestones, to cite no further instances, have been hardened and altered into marbles of crystalline texture. Intrusive veins and masses of granite and syenite are also known to have produced metamorphic effects on the rocks which they traverse. But in many instances no alterations of this kind have followed the intrusion of a vein or mass of unstratified rock amongst sedimentary deposits. Hence it is clear that although the intrusive rock must have been in a soft or plastic condition, it could not in these cases have been in a molten or intensely heated state. Occasionally also, solid granitic masses appear to have been thrust up amongst overlying strata, the intrusion being followed necessarily by signs of great mechanical disturbance. The condition of the quartz in granite and syenite, is opposed to the view of igneous fusion; and yet quartz of the same character does occur sparingly in many trachytes, and under conditions not favourable to the idea that it may have been subsequently introduced by aqueous agencies. Through these trachytes, moreover, there is a gradual passage into actual lavas or known fusion-products; whilst, on the other hand, many syenites (containing free quartz) merge gradually into greenstone and basalt, products intimately related to augitic lavas. It is, of course, impossible to say in what form a rock belonging now to the cruptive class may actually have originated. It may have been produced from an earlier formed igneous or crystalline mass, or from a sedimentary deposit buried deeply under overlying beds. The endogenous or subterranean agencies, whatever they may have been, that rendered granite and syenite plastic and crystalline, also produced the crystalline texture and other related characters of gneiss, mica schist, hornblende rock, and other members of the metamorphic series. It is now very generally assumed ! that whilst ordinary lavas and most trachytes and trappean (or basaltie) rocks have solidified from a molten condition, other rocks of this class the granites and sychites more especially, have been rendered plastic

and crystalline by "hydro-igneous" agency. These rocks, in other words, are thought to have undergone a kind of aqueous fusion and subsequent crystallization, the water, originally present in them, having been retained for a time by the pressure exerted on the plastic mass at great depths. But this view, it must be understood, is entirely hypothetical, and in many respects is far from satisfactory. All that is really known may be thus expressed :- Two sets of forces are concerned, either alone or conjointly, in the production of rock masses generally. One, entirely external, or due essentially to the action of the atmosphere and waters on the surface of the earth-mass, produces the sedimentary or stratified rocks proper. The other forces, of internal or subterranean origin, produce the unstratified rocks, as we now see these latter, and lead to the crystallization and metamorphism of sedimentary strata brought within their influence. But whether granites, syenites, traps, and trachytes, be igneous or non-igneous rocks, they are evidently related products, and members of a common class.

These rocks are arranged by <u>Sir Charles Lyell</u> in two broad divisions: <u>Volcanie</u> and <u>Plutonic rocks</u>; but it is impossible to draw a distinct line of demarcation between the two. <u>Granite and syenite</u>, for example, are placed in the Plutonic series, and <u>trachyte</u>, <u>greenstone</u>, <u>basalt</u>, &e., in the Volcanie division; but certain granitic trachytes connect the granites with the volcanic rocks; and in like manner, certain greenstones merge on the one hand into syenite, and on the other (the distinction between augite and hornblende, except in a purely mineralogical or crystallographic point of view, being now essentially broken down) they pass into augitic lavas. This equally effects the sub-division into Volcanic, Trappean, and Granitic rocks, adopted by other observers. I would therefore propose, as an arrangement of convenience, the distribution of the Eruptive rocks into the following groups: --1. Granites; 2. Serpentines; 3. Traps and Greenstones; 4. Tra chytes; 5. Obsidians; 6. Lavas.

1. <u>Granites</u>:—The rocks of this group possess, normally, a crystelline aspect and strongly-marked granular structure, the term granite being derived from the latter character. They are also especially characterized by the presence of free silica or quartz in a crystalline condition. They occur occasionally in broad straight veins or dykes, but are most commonly seen in the form of complicated, ramifying veins, or in large irregular masses which have often broken through and

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ERUPTIVE OR ENDOGENOUS ROCKS.

tilted up the surrounding rocks. Where a granite mass lies in contact with another rock, the latter will necessarily be the older formation if it be tilted up or otherwise mechanically affected by the granite, or if it be chemically altered near the points of contact, or if portions of its substance (in a more or less altered state) be enclosed within the granite mass, or if the granite run into it in the form of veins (Fig. 93). On the other hand, if the adjacent rock rest in undisturbed position on

the surface of the granite, and exhibit no chemical alteration, it may generally be inferred to

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be the more recent of the two (Fig. 94). Granitic veins frequently cross or intersect each other : intersected veins being necessarily older than those by which they are intersected. The diagram (Fig. 95) exhibits three veins of different ages. No. 1 is the oldest vein, as it is cut and also displaced or "faulted" by the other two. No. 3, again, is the most recent of the series, as it traverses and displaces both



FIG. 95.

No. 1 and No. 2. Granite rocks, ' by the decomposition of one of their essential components, feld, spar, have become converted in some districts into white or lightcoloured clays, largely used, under the name of kaolin, in the manufacture of porcelain. Granites. Felsites, and Syenites, with cer-

tain subordinate varieties, are the only rocks of the group hitherto recognised in Canada.

Granite, properly so-called, is composed of three minerals : quartz, feldspar, and mica. The feldspar is usually the potash species Orthoclase (see No. 57, Part II), but is occasionally represented by the soda species Albite (Part II, No. 58), or by Oligoclase (No. 59). The mica is generally the common potash species Muscovite (Part II, No. 77), but is sometimes mixed with, or occasionally replaced by, one of the magnesian micas. As a general rule, the quartz, in granite, occurs in vitreous colourless grains; the feldspar, in red, white, pink, or occasionally green or grey, lamellar masses, which exhibit smooth

and somewhat pearly cleavage planes; and the mica is mostly in small scales, or larger foliæ, of a pearly-metallic aspect, and silvery white, black, brown, pearl-grey, or greenish colour. In coarse-grained granites, these component minerals are readily distinguishable; but in rocks of fine-grain, they become blended into a common granitic mass. The mica frequently dies out, or is very sparingly present, in which case the rock is sometimes known as *Pegmacile*, but this name is applied by German lithologists to coarse-grained granites containing a small amount of silvery-white mica in comparatively large scales or leaves. Occasionally also in these quartzo-feldspathic granites, the quartz is arranged in the form of narrow irregular crystals in more or less distinct

bands, producing, in transverse sections, the appearance of a cuniform or Assyrian inscription : whence the term "graphic granite" sometimes bestowed on this variety. When again, the quartz and feldspar become intimately blended, so as to possess more or less the appearance of



FIG. 96.

a simple mineral, the rock has been termed *Felsite* or *Petrosilex*. Very frequently, through a base of this, or of ordinary granite, numerous crystals of feldspar are distributed, when the rock is known as *porphyry*, or, better, as *porphyritic granite* or *felsite* (Fig. 97). The



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imbedded crystals often show the twin or compound structure so common in feldspathic silicates. The term "porphyry" (from $\pi o \rho \varphi o \rho a$), as the name would indicate, was originally applied to rocks of this kind in which either the base or the

imbedded crystals presented a deep-red colour, but it is now bestowed conventionally on all rocks containing distinct crystals of feldspar or other minerals. We have thus perphyritic granites, perphyritic syenites, perphyritic trachytes, perphyritic greenstones (the original perphyry having been probably one of these latter), perphyritic lavas, &c. Finally, as regards other granite varieties (to many of which special names of uncertain or merely local application have been uselessly given), it may be observed that the mica of ordinary granite is occasionally replaced by tale, giving rise to *talcose granite* (the *Protogine* of some authors), or is accompanied at times by hornblende, the rock

in the latter case being known as syenitic or hornblendic granite. When hornblende is wholly or essentially substituted for mica, a syenite results. This latter term is restricted however by most German lithologists to a mixture of orthoclase-feldspar and hornblende, in which free quartz is absent or only accidentally present. By the gradual diminution of quartz, the granites proper pass into granitic trachytes, described below; and they are represented in the metamorphic series by gneiss and gneissoid rocks generally, into which also they appear locally to merge.

Examples of intrusive granite occur in many parts of the large area occupied by the Laurentian rocks of Canada (see Part V). Porphyritic felsite, in which the base is mostly dull-red or greenish-black, and the imbedded feldspar crystals red or pink, is seen in connection with a large mass of syenite in the Township of Grenville on the Ottawa. This variety, sometimes termed Orthophyre, is scarcely perhaps a true granite, but as it contains free quartz it must be referred conventionally to the granitic series. A broad dyke or vein of graphic granite (consisting of quartz and orthoclase-feldspar) is described in the Reports of the Geological Survey as occurring on Allumette Lake, . north of Pembroke, and other examples of a similar character have been recognized in the neighbouring township of Ross. Veins of both ordinary and quartzo-feldspathic granite, in some cases holding crystals of tourmaline or schorl, occur also more or less abundantly, in St. Jerome, Escott, Lansdowne, Burgess, Madoc, Marmora, Galway, and indeed throughout the Laurentian region generally, lying between the Ottawa and Georgian Bay. In Laurentian strata, likewise, on the River Rouge, east of the Ottawa, and at Stony Lake in the Township of Dummer or Burleigh, as well as in Bathurst and Burgess, granitic veins containing albite or soda-feldspar replacing or accompanying orthoelase, have long been known. The opalescent variety of Albite known as Peristerite (see Part II, No. 58) comes from a vein of this kind in Bathurst. Other veins and some considerable masses of granite occur on the north and north-east shores of Lake Superior, as in the vicinity of Michipicoten, at Point-aux-Mines, and here and there about Bachewahnung Bay, and elsewhere. A mass of red granite, inferred by Sir William Logan to be of Huronian age, is described as having broken through and tilted up Laurentian gneissoid strata south of Lake Pakowagaming on the north shore of Lake Huron; and gra-

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nitic dykes and veins occur in the Bruce Mines District. A flesh-red granite underlies beds of Trenton limestone in the township of Storrington, north of Kingston. Finally, intrusive masses and dykes of white or light-coloured granite, apparently of Devonian age, occur on Lake Memphremagog in the township of Stanstead, and others in the townships of Hereford, Barnston, and Burford, of that district. Similar masses have been noticed on Lake St. Francis, Lake Megantic, and in the intervening townships. Some of these granitic masses, as described in the Revised Report of the Geological Survey (1863), cover areas of from six to twelve square miles.

A granite which contains hornblende in place of mica, is defined by most geologists as Syenite, but this term, as stated above, is restricted by many German lithologists to a granitic greenstone, or mixture of orthoelase and hornblende (see below). Keeping, however, to the general definition, we have in syenite a more or less distinctly granular aggregate of quartz, potash- or soda-feldspar, and hornblende : the feldspar being usually red or white, and the hornblende green or black. The quartz grains are generally less abundant than the other components; and when they become indistinct, the rock gradually merges into a granitic greenstone or diorite. As in ordinary granite both coarse and fine-grained varieties of syenite occur. In the latter, the component minerals are blended into a more or less uniform dark-green mass, and the rock resembles, and can rarely be distinguished from, an ordinary compact greenstone. From this trappean rock into welldefined sygnite indeed, an evident transition may be occasionally traced. On the other hand, syenite is represented in the Metamorphie Series by syenitic gneiss, and to some extent by amphibolite or hornblenderock. Syenite, as already explained, is very frequently porphyriticred or occasionally white crystals of feldspar appearing on a dark or black ground, or green or black crystals of hornblende being imbedded in a reddish granular mixture of the usual components.

In Canada, eruptive sycnites (as defined above) appear to be confined entirely to Laurentian areas. The most remarkable example is the great sycnitic mass described by Sir W dliam Logan as covering **a** space of about thirty-six square miles in the townships of Grenville, Chatham, and Wentworth, near the left bank of the Ottawa. It consists chiefly of red and white orthoclase, with black hornblende and **a** little quartz; mica being also present in one portion of the mass, which

ERUPTIVE OR ENDOGENOUS ROCKS.

thus shews a transition into syenitic granite. Dykes pass from the main body of the syenite into the surrounding beds of crystalline linestone and gneiss. Two other series of dykes or eruptive masses occur in connection with the syenite of this locality. Some of these masses, consisting of a compact base of petro-silex, or intimate mixture of quartz and feldspar, with imbedded crystals of red orthoclase and fragments of gneiss and other rocks, traverse the syenite, and hence are of newer origin; whilst others, consisting of trap or greenstone, are cut off, or interrupted in their course, by the syenite, and are therefore of anterior date. Dykes of syenite also occur, here and there, throughout the Laurentian country between the Ottawa and Lake Superior.

2. Serpentines :— These rocks are simply varieties of the hydrated magnesian silicate, Serpentine (Part II, No. 83). Most serpentinerocks occur in beds, and belong consequently to the Metamorphic Series; but undoubted examples of eruptive serpentines have been recognized in Tuscany, Cornwall, and other localities. These may consist, however, of dykes of altered trap or greenstone. Serpentinerock in veins, dykes, or irregular masses, is either granular or compact in texture; more or less soft and sectile; and usually of a green, greenish-yellow, brown, reddish, or yellowish-grey tint, several shades or varieties of colour often occurring together in streaks or patches; but the serpentine-rocks of Canadian occurrence belong entirely to the Metamorphic Series, and are described consequently under that division.

3. <u>Traps and Greenstones</u>: — The rocks of this series present a somewhat variable composition, but <u>consist essentially of</u> some kind of <u>feldspar</u>—usually Labradorite or Albite—or a mixture of feldspars, with <u>augite</u>, <u>hornblende</u>, or chlorite Many also contain in addition, a mixture of zeolitic minerals, nepheline, magnetic and titaniferous iron ores, grains of olivine, scales of mica, carbonates of lime and iron, and other substances. But free silica or quartz is altogether absent, or is present only as an accidental or inessential constituent. The texture of these rocks is of two general or principal kinds: (1), compact or homogeneous; and (2), distinctly granular or granitic: but finegrained examples offer a transition from the granitic to the compact structure. In the latter, the component minerals are blended into a common or uniform mass, chiefly, unless weathered, of a grey, green or black colour. In each of these varieties of texture, a porphyritic A COLOR AND THE REAL AND A COLOR AND A COL

structure (see Fig. 97, above) may also be present—the imbedded crystals consisting of albite, oligoclase, augite, hornblende, or some other mineral. The compact varieties also frequently exhibit an amygdaloidal structure, Fig. 98, the rock being full of oval or irregularly-



shaped eavities, usually of small size, and either empty or more commonly lined or filled with amethyst, agate, or other varietics of quartz ; or otherwise with calespar, various zeolites, green-earth, &c. These compact varieties, moreover, of both trap and greenstone very often assume a columnar or basaltiform structure, as in figure 99. In this case the rock exhibits a kind

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of rough crystallization, and contains numerous joints or partings in the direction of which it separates more or less readily, forming prisms or prismatic masses of from three to eight or nine sides: and as these possess also transverse joints at right angles to the axis of a prism, a flat, tabular, and step-like outline is very

FIG. 99.

generally presented by columnar or sub-columnar varieties of this kind. Hence the term "<u>trap</u>" or "trappean rock," from trappa, a Swedish word signifying a set of steps—attention having first been called to this peculiarity by Swedish observers. A good example is presented by the promontory of Thunder Cape. Fig. 100, on the north-west shore of

Lake Superior, in which five very distinet steps are observable, more especially when viewed from a certain distance. The eruptive



mass of McKay's Mountain on the other side of Thunder Bay, as well as similar rocks on Pie Island and elsewhere in that district, exhibit also well-marked illustrations of this step-like outline, although most of these rocks present only a sub-columnar structure. According to Sir

ERUPTIVE OR ENDOGENOUS ROCKS.

William Logan, a similar step-like outline is exhibited by some large dykes of columnar dolerite in the township Grenville on the Ottawa.

As regards their general conditions of occurrence, greenstones and traps are seen very commonly in the form of more or less broad and straight or simply-forking veins (Fig. 101), technically known as



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dykes. This term originates in the fact that trappean veins usually possess greater powers of resistance, than the rocks which they traverse, to the docomposing influences of the atmosphere or the destructive action of water: in consequence of which they often project

from the face of cliffs or hill-sides, or stand up above the general surface of the ground, and thus resemble in many cases the stone fences or walls known in certain localities as "dykes." The annexed figure exhibits a diagram-view—the surrounding foliage, &c., being

omitted—of a projecting dyke of this kind, as seen on Slate River, a small rocky stream which enters the Kaministiquia about twelve miles above Fort William on Thunder Bay, Lake Superior. The high cliffs of aluminous slate or shale on each side er' the ravine through which the river flows, have been wasted by atmospheric action to a much greater extent than the dyke; and the latter thus



Lands out from the face of the cliff on each side of the ravine, and presents the appearance of an old Gothic wall. On one side, it comes down close to the bank of the stream, as seen in the figure; and the arch, there shewn, must have been hollowed out, when the water flowed with fuller volume and at a somewhat higher level, during the gradual excavation of the valley. Most of the projecting points, reefs, and rocky islets on the shores of our northern lakes, consist of denuded portions of

trappean dykes. Occasionally, however, trap and greenstones decompose more readily than the surrounding or eneasing rock. Trench-like depressions in the ground, or clefts and open fissures on the face of the rock, are thus produced. Examples may be seen on some of the islands and parts of the coast of Lake Superior, near Neepigon Bay, and elsewhere.

Traps and greenstones occur also, in many districts, in the form of flat tabular masses, resting upon hill-tops. These are merely portions of ancient dykes, exposed and isolated by denudation. Finally, mountain-masses composed of trappean and greenstone rocks are of frequent occurrence, but these also may be regarded in most cases as the more semicat portions of enormous dykes, several being often seen to lie in the same general direction, as though along an extended line of fissure. The picturesque mountain of Montreal, and the mountains of Belœil, Monnoir, Rougement, &c., are examples. These salient masses exhibit in places a distinctly conical or partly truncated form, as seen in the outline of the "Paps," (Fig. 103), on the east side of



FIG. 103.

Black Bay, Lake Superior, and to some extent, also, in many of the greenstone hills of the Eastern Townships. A steplike and more or less tabular outline, as already remarked, is likewise very characteristic of rock masses of this group.

The variable composition and diversities of structure exhibited by trappean rocks have given rise on the part of lithologists to the formation of a great number of so-called species, each provided with a distinct name, usually of Greek derivation. But these attempted distinctions are in many instances of purely local application; and in very few cases can they be regarded as indicating definite admixtures of ready recognition. Names applied to particular varieties by one author, are applied quite differently by others. The terms melaphyre, porphyrite, diabase, &c., might be eited as examples. In many cases also, the same rock, if presenting slight differences of texture, or if assumed, without any possibility of proving the assumption, to contain augite in one case and hornblende in another, is described under different species. In this manner, fanciful distinctions which have no true fean-

ERUPTIVE OR INDOGENOUS ROCKS.

dation in Nature, and which eannot be rigorously or definitely applied, are attempted vainly to be carried out in many so-called systems of lithology. If minute chemical or mineralogical differences were regarded as essential, our Canadian varieties of this group of rocks might add many names to the already uselessly extended list. It is not possible however in the present state of the question, nor is it desirable in an elementary work of this character, to depart altogether from the beaten track. Retaining therefore some of the more generally recognised names and distinctions, whilst duly admitting the more or less arbitrary and uncertain character of these, we may refer our) Canadian rocks of the Trappean series to the following varieties : (1) Trap or Basalt; (2) Dolerite or Granitoid Trap; (3) Greenstone or Aphanite; (4) Diorite or Graniteid Greenstone; (5) Diabase or Chloritie Trap. These varieties, it must be understood, merge more or less into each other, so that in many instances a rock might be referred with equal justice to two or more of their included types.

Trap or Basalt may be defined conventionally as a black, greenishblack or dark-grey rock of compact texture, composed of an intimately blended mixture of lime-feldspar (or lime and soda feldspars), augite, 'magnetic and titaniferous iron ores, zeolitic silicates, and carbonates of lime and iron. In some kinds, the feldspar is replaced by nephcline; and olivine, in visible grains of a green or greenish-brown colour, is very generally present in basaltic rocks. These component minerals are deduced by calculation, it will of course be understood, from the separate ingredients, silica, magnesia, lime, &c., obtained in the enalysis of the rock. Altered or weathered varietice of trap are frequently of a dull brick-red or brown colour, the change being caused by the higher oxidation of the iron. Unaltered basalts are always more or less strongly magnetic, easily fusible, and partially attacked by acids. Sp. gr. 2.9 to 3.1, but occasionally somewhat less from privid alteration of the rock.

The more common varieties or sub-varieties comprise:—(a) Massive or amorphous trap; (b) Slaty trap; (c) Columnar and sub-columnar trap (Fig. 99), the variety to which the term basalt is more generally applied; (d) Amygdaloidal trap (Fig. 98), containing oval or other shaped cavities mostly filled with agates, zeolites, cale-spar, green earth, &c., as explained on a preceding page; (c) Porphyritic trap, containing imbedded crystals of albite, augite, or other minerals. Examples





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of massive and porphyritic trap (consisting in places of almost pure augite or pyroxene, and hence termed "pyroxenite" by some observers) occur more especially in the Montreal Mountain, and in various parts of the Eastern Townships and lower St. Lawrence district. Columnar and sub-columnar trap is abundant around Thunder Bay; and amygdaloidal trap is of common occurrence along the northern and other shores of Lake Superior, the north shore of Lake Huron, and elsewhere. The agates of Michipicoten Island, Agate Island, and other spots on Lake Superior, are derived from the disintegration of these amygdaloidal rocks.

<u>Dolerite</u> is simply a trap or basalt of granitoid structure, in the coarse-grained varieties of which the component minerals are more or less perceptible, individually. Fine-grained varieties, which offer a transition into basalt proper, have been classed apart, by some lithologists, under the name of *Anamesite*. In these, the component minerals are scarcely, if at all, observable. Dolerites, as a general rule, are chiefly of a greyish colour, varying from light-grey with black specks and indistinct crystals of augite, to an almost uniform black or dark grey tint. When much olivine is present, and occasionally in other cases, the rock assumes a greenish-grey or brownish-green colour; and weathered examples are frequently rusty-red, or otherwise dull white. Sp. gr. = 2.7 - 3.0.

This granitoid condition of trap presents, as in ordinary basalt, massive, slaty, columnar, amygdaloidal, and porphyritic varieties. Examples occur generally throughout Canadian districts in which trappean rocks prevail; especially in the Townships of Grenville, Chatham and Wentworth in the Ottawa region; also in parts of the Mentreal Mountain and in the mountains of Montarville and Rougemont, and other parts of that district; abundantly also on the shores and islands of Lake Superior, (Gros Cap, Goulais Bay, Montreal River, &c.,) and throughout the northern lake region generally. The dyke on Slate River, shown in figure 102, consists of grey dolerite.

<u>Greenstone</u> or <u>Aphanite</u> is a compact trappean rock of a more or less decided green colour, passing into greenish-black. It is assumed from its general composition to be made up of an intimate mixture of lime and soda feldspars and hornblende, with very generally a certain amount of magnetic and titaniferous iron ores, and some carbonate of lime. Strictly, it cannot be distinguished, except conventionally by its

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ERUPTIVE OR INDOGENOUS ROCKS.

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green colour, from ordinary trap. It presents massive, slaty, columnar, amygdaloidal, and porphyritic varieties, and passes into diorite and diabase, the latter by the addition of chlorite, as well as into common trap. Dykes of this green variety of trap occur here and there on Lake Superior, but most of the so-called greenstones of that region are evidently chloritic, and hence would be regarded by systematists as compact and amygdaloidal varieties of diabase. Dykes of somewhat similar character occur also in the Madoe and Marmora region, and undoubtedly in other districts. The terms Greenstone and Aphanite, it should be observed, are applied by some authors to compact varieties of Hornblende Rock and other hornblendic examples of the Metamorphic series.

Diorite is the name commonly given to a granitoid trappean rock made up of more or less distinctly visible grains or imperfect crystals of a soda-feldspar (or lime-feldspar) and hornblende, and containing verj frequently, in addition, small grains of carbonate of lime, particles of magnetic iron ore, scales of mica, sphene, and other minerals. It passes into compact greenstone by almost insensible transitions; and in many cases it cannot be distinguished readily, if at all, from varieties of dolerite or granitoid trap. Its feldspathic portion is usually white or grey, or sometimes reddish, and the hornblende black or green; but fine-grained examples have very commonly a distinct green colour throughout. Massive, slaty, columnar, amygdaloidal, and porphyritic varieties occur, as in other kinds of trappean rock. The specific gravity varies from about 2.6 to 2.9.

Examples of diorite, of a more or less granitic aspect from the frequent presence of small scales of brown mica, occur in the eruptive masses of Belœil, Monnoir or Mt. Johnson, Rigaud, and Yamaska, of the Eastern Townships of Canada. Other examples, passing here and there into diabase, are seen at several spots on the shores of Lake Superior, as near Michipicoten Harbour and elsewhere in that neighbourhood, Batchewahmung Bay, &c. The term diorite, it must be remembered, has also been applied by certain authors to some of the stratified hornblendie rocks of the Metamorphic Series—these crystalline strata representing, as regards general composition many diorites and other intrusive rocks containing hornblende, just as the gneissoid strata represent the granites and syenites. To avoid confusion, however, the term if employed at all, should be restricted, in accordance

with common usage, to intrusive or eruptive rocks. If the same term is to be applied indefinitely to a stratified and eruptive form of rock, it follows logically that the term gneiss should be abaadoned, and all the micaecous examples of gneiss should be known as granite, and the hornblendic varieties as system—a system, we presume, that few geologists, apart from those of a certain school, would be inclined to follow.

Diabase or Chloritic Trap-as defined by most authors-is an eruptive rock containing of augite or hornblende with a certain amount of chlorite: carbonate of lime being very generally present as an additional constituent. The term "diabase" is often applied, however, to chloritic and other varieties of hornblendic and augitic rocks belonging to the Metamorphic Series. Some kinds of eruptive diabase have also been described as melaphyre, but this term is also vaguely applied to many diorites and other graaitoid rocks of the present group. Compact varieties, which are mostly of a decided green colour, pass into compact trap and greenstone by insensible transitions. Granitoid varieties merge also into dolerite and diorite. Both kinds offer amygdaloidal, perphyritic, and other examples. The feldspar in coarse-grained examples is either groyish-white, greenish, reddish, or brownish; and the chlorite presents the form of small scales and particles of a green colour. Weathered examples are usually dull-brown or red. Varieties of diabase, as thus defined, occur both in the form of dykes and in intercalated bedded masses among the Huronian strata of Lake Superior, as in Michipicoten Island, as well as at Cros Gap, Cape Maimanse, Point-aux-Mines, Goulais River, and elsewhere. The bedded examples may perhaps be really metamorphosed strata, but they consist most probably of portions of ancient trappean overflows formed during the gradual building up of the Huronian deposits. Some contain epidote; others enclose well-defined erystals of augite; and many are in the condition of calcareous amygdaloids.

<u>Trachytes</u>:—The rocks of this division are essentially feldspathic in composition, the more typical or characteristic examples consisting almost wholly of orthoclase or potash-feldspar. Many of these are more or less porous or vesicular in texture, and are thus peculiarly harsh or dry to the touch, whence the name "trachyte," from <u>trazos</u>, rough. This character, however, will only apply to certain varieties, as many trachytes do not differ in this respect from other rocks. Most trachytes are white, light-grey, or pale reddish in colour; but in the granitoid

ERUPTIVE OR ENDOGENOUS ROCKS.

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varieties the presence of scales of brown mica, small crystals or particles of green or black hornblende, and other accessory minerals, gives rise to a darker and variable tint. These trachytic rocks merge into members of the granitic and trappean series on the one hand, and into ordinary feldspathic lavas on the other. The substance known as pumice, for example, may be referred both to trachyte and to lava. Thus, many trachytes, occurring in connection with active or extinct volcanic cones, are actual lavas in the common sense of the term; but others, although undoubtedly of similar origin, occur in localities to which the term volcanic has ceased to apply. Viewed generally, although no marked lines of demarcation can be drawn between them, the Trachytes present the following leading varieties :-- Common or Porous Trachyte; Compact or Massive Trachyte; Slaty Trachyte; Granitoid Trachyte, Examples of porphyritie structure occur in each of these varieties; and in the trachytes of some localities the feldspar consists partially or wholly of soda or lime species.

Common Trachyte is met with chiefly in regions in which active or extinct volcanoes are distributed. It is more or less porous, or of an open-granular texture, and is frequently porphyritic from inclosed erystals of glassy feldspar. Scales and speeks of mica, &c., are sometimes scattered through it, and it contains occasionally some grains of quartz. The latter mineral is altogether of exceptional occurrence, but its occasional presence serves to connect the trachytes with granitic rocks. Compact Trachyte, also known as "white trap" or "feldspar trap," occurs in broad veins or dykes traversing both the older trap or dolerite of the Montreal Mountain and the Lower Silurian limestones of that neighbourhood. It contains at these localities a considerable amount of intermixed carbonate of lime; whilst a related variety of somewhat slaty structure, from near Lachine, is partly zeolitic in its composition, and would thus be known by many lithologists as a phonolite. These examples are partially in an earthy state, a condition sometimes recognized by a special name, that of *Domite*, a term applied to the earthy or semi-decomposed trachytes of the Puy-de-Dôme in the ancient volcanic district of Central France. A porphyritie variety of pale-red or yellowish trachyte, holding large crystals of feldspar, occurs also at Chambly. Examples of Granitoid Trachyte are especially abundant in the Eastern Townships of Brome and Shefford where they form eruptive masses of considerable extent and elevation. The tra-

chytes of these mountains are both coarse and fine granular, and are composed of orthoclase or other feldspars with intermixed scales of brown or black mica, grains of yellow sphene and magnetic iron ore-Small crystalline particles of black hornblende are also occasionally present. In the Yamaska Mountain of the same district, a micaceous rock of this character changes somewhat in the composition of its feldspar, and becoming strongly hornblendic, passes into a variety of diorite; but the distinction between granitic trachyte and diorite is in many cases purely artificial.

5. Obsidians and Pitchstones : - This division includes lavas, and other rock matters of igneous origin, which occur in a more or less vitreous or glassy state, and present an essentially feldspathic composition. The term obsidian is usually restricted to grey, green, brown, or black rocks of this character, occurring in actual connection with volcanoes, either active or extinct. A variety containing small spherical concretions of a somewhat pearly aspect is known as Pearlstone. These rocks break with sharp edges, and the fractured surface shows conchoidal markings. Pitchstone occurs chiefly in the form of dykes in trappean districts. It is mostly of a black colour and pitchlike or resinous aspect, but some varieties are dull-green, grey, or red. A porphyritic variety, traversed by small veins of agate, occurs near the deserted copper workings on the Island of Michipicoten, Lake Superior; and some of the dykes and bedded traps near Michipicoten Harbour on the mainland, appear to be intermediate in character between pitchstone and ordinary basalt.

6. Lavas :--These comprise the actual rock-matters which issue in a molten condition from volcanoes. They present vesicular, compact, columnar, porphyritic, and other varieties, and are of two general kinds as regards composition : <u>feldspathic</u>, and <u>feldspatho-augitic</u>. The first, and by far the more common of the two, are composed essentially of feldspar, and are mostly of a light or dark grey colour. They pass into trachytes. The second, composed essentially of feldspar and augite, are dark-green or black in colour, and are undistinguishable, except by their actual conditions of occurrence, from many traps and greenstones. Examples of the group, as thus defined, are unknown within the limits of Canada.

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In a review of the characters and conditions of occurrence of rockmasses, the subject of mineral veins cannot be altogether passed over, but the scope of the present work admits only of a general reference to this subject.

Mineral veins may be defined as cracks or fissures in the Earth's crust, filled or partially filled with stony and metallic matters. In some veins, stony or sparry matters, as quartz or cale spar, are alone present; but these matters are very generally accompanied by metallic sulphides, oxides, or other compounds, and occasionally by native metals. The sparry or stony substances are then known as gangues or veinstones. The more common veinstones comprise : quartz, cale spar, fluor spar, and heavy spar—two or more of these being frequently present together.* In the higher part of a vein, frequently to a depth of several fathoms from the surface, the gangue and ores are often in a partially decomposed or earthy condition.

A mineral vein thus forms a more or less compressed sheet of mineral matter, extending often to unknown depths, and being frequently traceable for several miles across a line of country. Some veins are less than an inch broad, whilst others occasionally exceed twenty or even fifty feet in width. Many of the veins containing native silver in the district around Thunder Bay on Lake Superior, are at least twenty feet wide, and some are wider. A vein of calc spar, carrying galena, at the Frontenae Mining Location in the Township of Loughborough (north of Kingston) is very nearly as wide, although the workable portion is limited to about twelve feet in breadth. As a general rule however, few veins exhibit a greater average width than three or four feet; and in nearly all cases a vein contracts and expands more or less at different depths, or in different parts of its course. Many veins traverse the enclosing rocks, or "country," almost or quite vertically; others incline at a greater or less angle, the inclination being commonly termed the "underlie" or "hade;" and some again run almost horizontally, or like a narrow bed, for certain distances. The sides of a vein are known in mining language as the walls. These are very often separated from the enclosing rock by a band of brown ochreous matter or gossan, arising from the decomposition of pyrites,

^{*} See descriptions in Part II-Nos. 43, 88, 106, and 96, respectively.

or by a layer of elay or other soft or earthy material. This is technically known as a "selvage." It usually facilitates the working of the

vein. A broad selvage of this character lines the south wall of the Frontenac vein, referred to above. In inclined veins, the upper wall is generally termed the "hanging wall," and the lower, the "foot wall" or floor. A and B, in Fig. 104, illustrate these positions respectively.



Fig. 104.

Mineral veins occur chiefly in mountainous or geologically-disturbed districts; and although present in certain localities among unaltered strata, they prevail mostly in metamorphic regions, especially where these are broken through by cruptive masses and dykes of granitic or trappean rock. In the Provinces of Ontario and Quebec, they occur chiefly in four districts : - First, in the Laurentian country lying between the Ottawa and Lake Huron, as, more especially, in the counties of Carleton, Lanark, Leeds, Frontenae, Hastings, Peterborough, and Victoria; secondly, in the allied Huronian strata on the north shore of Lake Huron; thirdly, in more recent metamorphic rocks on the shores and islands of Lake Superior; and fourthly, in metamorphic strata of apparently the same general age as those of Lake Superior, in the Eastern Townships and adjoining region south of the St. Law-These districts, as regards their geological relations, are rence. described in Part V.

In reference to form and geological position, four different kinds of veins have been recognized. These comprise :---(1) Independent or . ordinary veins, consisting of well-defined fissures which pass through rocks of various kinds, and generally hold a more or less straight course, whilst extending at the same time to great depths. In mining localities, several veins of this kind are commonly found to run in the same direction at greater or less distances apart. If crossed by another series of veins, the latter are usually found to carry ores of a different nature. The course of these veins may often be traced by trench-like depressions in the ground, arising from the atmospheric decomposition to which the surface of the vein has been subjected; but in some cases, especially when the gangue consists essentially of quartz, the vein has weathered to a less extent than the surrounding rocks, and thus stands

MINERAL VEINS

up in ridge-like form above the surface of the ground. werks. This term, borrowed from German miners, is used to denote a series of usually narrow veins, ramifying amongst each, and uniting occasionally into bunches or pockets of ore. (3) Contact veins. These are ordinary voins lying in immediate contact with eruptive masses. Very frequently, for example, a band of metalliferous matter is found to lie between the edge of a mass of granite or trap and the enclosing stratified rock, in which case it is said to occur in the "contact country" (4) Gash veins. These are simply surface elefts or fissures of slight depth or extent. They are commonly filled with galena, and differ usually if not always from ordinary veins by the absence of veinstones properly so-called. In many cases they form mere strings of metalliferous matter. Attempts have been made to work deceptive veins of this character, in the townships of Eramosa,

Mineral veins may also be arranged to some extent as regards their structure or texture in five groups, as follows :- (1) Compact veins. In these, the fissure is filled entirely with a solid and more or less uniform mass of ore. (2) Open veins. The fissure, in these veins, is only partially occupied by mineral matter, open spaces occurring throughout the vein generally. Large eavities or "vugs," often lined with fine crystallizations, occur here and there in veins of various kinds; but in these open veins, so-called, the insterstices or free spaces are especially numerous. (3) Banded veins. These are filled or lined with distinct bands or zones of different substances, the bands of the two walls corresponding in character, as in the annexed figure. The two outer bands, or those against

the walls, may consist, for example, of brown ferruginous gossan, the two next of quartz, the two within these, of copper pyrites, succeeded by zinc blende, quartz, calespar, galena, or other substances, in regular banded alternations. Veins of this kind are exceedingly abundant

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in many mining districts, but characteristic examples are rare in Canada. (4) Spheroidal Veins. In these the ore lies in the gaugue in the form of spheroidal masses composed of concentric layers. Well-defined examples of Canadian occurrence do not appear to have been recorded,

(5) <u>Brecciated Veins</u>. These form the great majority of mineral veins hitherto observed in Canada. The gangue contains angular and other fragments of wall-rook, with the metalliferous portions of the vein arranged between and around these, occasionally in more or less distinet layers. The rock-fragments are often traversed by thin strings of ore. When of large size, they form the so-called "horses" of the miners. These horses sometimes cause a good deal of trouble by coming in a direct line with the shaft, as happened at the Shuniah vein on Thunder Bay, Lake Superior, and in one of the shafts at the Ives Mine in the Eastern Township of Bolton.

Great obscurity prevails with regard to the processes by which vein-fissures have been filled with their contents; but, in the majority of cases, several distinct agencies, acting both simultaneously and consecutively, have evidently been concerned in the repletion of these fissures. Some observers have sought to maintain that all the various matters found in veins were originally diffused through the mass of the surrounding rocks, and were drawn into the fissures by electrical currents passing through these : although they fail to explain how currents of this kind could possibly effect the operation in question. Others assume the mineral matters, in veins, to have been extracted from the surrounding rocks by the solvent power of water, and thus to have been gradually earried into the fissure. Many of the sparry, and some of the metallic matters, occurring in veins, many have been derived in this manner from the surrounding rocks; but the supposed presence of diffused metallic matters in these rocks, considered generally, is, it must be remembered, entirely hypothetical, and open to many objections. On the other hand, we have undeniable proofs in volcanic and other districts, that metallic matters, in many respects similar to those found in veins, or capable of being converted into such by known chemical changes and decompositions, are actually brought from deeply-seated sources, both as sublimed products, and in solution in thermal springs. The weight of evidence, therefore, leads to the inference that the contents of veins generally, are due to endogenous action, rather than to surface forces; or that veins, in other words, have been filled essentially from below. In this connection, it must be remembered that many veins penetrate to unknown depths, and have yielded sulphurized or other ores, without being yet exhausted, to the amount of thousands of tons Whilst many products found in veins are probably due in part or wholly to sublimation, the great majority of these products would certainly

MINERAL VEINS.

appear to have been deposited from solution : not necessarily in the condition in which they now appear, but in some other form from which their present condition has been derived. According to certain theorists, the whole of these bodies have been deposited from aqueous solution, but it is not easy to reconcile facts in all cases with this assumption. Such changes and decompositions as now take place in veins, lead to the conversion of many sulphurized ores into sulphates, carbonates, and other oxidized compounds; but do not bring about, as the above hypothesis would require, the conversion of these latter on the large scale into vast bodies of galena, copper pyrites, arsenical pyrites, and other non-oxydized ores. But if these ores, now found in such vast quantities in mineral veins, really originated from soluble sulphates, chlorides, &c., the latter must undoubtedly have come from some deeply-seated source; and their conversion into non-oxidized bodies could not have taken place on this enormous scale without the further collaboration of endogenous agencies.

Mineral veins are generally opened by shafts and adits, or by both of these methods combined. In the case of veins with considerable underlie, the shafts, or openings from the surface of the ground, are

often earried down along the slope of the vein; but, in general, shafts are sunk vertically, and cross-cuts are carried from the sides of the shaft at regular intervals to the intersection of the vein. Galleries are then driven along the course of the latter at these points, and the sheet of ore lying between each pair of galleries or "drifts" is extracted by a system of steplike excavations, technically

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FIG. 106.

known as "stoping." When a vein is nearly vertical in its position, a shaft may of course be carried down to a great depth upon the substance of the vein itself, and the material thus taken out of the shaft will often pay for the sinking of the latter. Shafts are usually reetangular in form, and are not only strongly framed at the sides, at least for a certain depth, but are commonly sub-divided vertically into two 13

or more compartments by brattice-work or planking : one of these compartments being reserved for the pump-rods and also for the buckets or kibbles used for sending up the ore, or bringing it, in technical phrascology, to grass; and another being fitted with ladders, or with a special lifting apparatus, for the miners. An adit is a horizontal or nearly horizontal gallery driven from the side of sloping or escarped ground, so as to strike the vein at a certain depth from the surface outcrop of the latter. It serves in many cases, especially where it opens on a river bank, or on ground suitable for a tramway, &c., as a convenient roadway for bringing out the ore; and if at a sufficiently low level it may greatly facilitate the drainage of the mine, and assist in the ventilation of the works. Where two shafts are sunk upon the vein, they should be located, if possible, on high and low ground, respectively, in order to promote ventilation. The ore, when brought to the surface, is usually "cobbed" or hand-dressed by children, and the assorted portions, thus broken up by hammers, are brought into the state of powder by subjection to stamps or crushers. The powder is then agitated with water in long narrow troughs or flat circular tubs called "buddles," the latter kind being furnished with revolving arms or sweeps to which brushes are attached, or it is shaken up with water in "jiggers" or tubs provided with moveable sieves, until the metallic particles by reason of their greater weight collect together, and so become separated more or less thoroughly from the lighter earthy particles or refuse, commonly known as waste slimes or tailings. The dressed or concentrated ore is then ready for the furnace or reducing works.

Veins often cut or cross each other or are cut by eruptive dykes. In this case the intersected vein is very generally faulted or displaced. In mining language, a break of this kind in the continuity of a vein is commonly termed a "trouble," "heave," or "thrust," or an "upthrow" or "downthrow" as the case may be. The displacement may be very slight, or it may exceed many fathoms; and



F10. 107.

great expense is often incurred in seeking for the displaced portion of

RELATIVE AGES OF ROCK GROUPS.

a vein thus affected. As a general rule, if the intersecting vein or dyke be entered at its hanging-wall, as in working from A to A', Fig. 107, the continuation of the broken vein may be looked for "uphill;" whereas, if the intersecting vein or dyke be entered at its footwall, or at B', the search for the displaced vein should be made "down-hill." This rule is not without its exceptions, but the exceptions are comparatively rare.

In order to ascertain the depth at which an inclined vein or bed of any kind may be reached by vertical sinking at a given depth from its

outcrop, as at S, for example, in Fig. 108, we have the formula: $s = \tan i \times d$; or, $\text{Log } s = \log \tan i + \log d$; in which s = the depth of the shaft; i = the dip or inclina-



FIG. 108.

tion of the vein in degrees or minutes; and d = the distance between the outcrop and the mouth of the shaft. If the ground at the proposed site of the shaft be higher or lower than at the outcrop of the vein or bed, the difference of level must of course be added to or deducted from s, as the case may require.

VI. CLASSIFICATION OF ROCK MASSES IN ACCORDANCE WITH THEIR RELATIVE PERIODS OF FORMATION.

Viewed in reference to their modes of derivation or general formative processes, rocks admit, as we have seen, of a distribution into three leading groups : comprising Sedimentary, Metamorphic, and Eruptive rocks : but they admit also of another and far more interesting classification, based on their relative ages or periods of formation.

It is now universally conceded, on proofs the most unanswerable, that the various sedimentary and other rocks which make up the solid portion of our globe, were not formed during one brief or transitory period, but were gradually elaborated or built up during a long succession of ages. In areas of very limited extent, for example, even in the same cliff-face, or in excavations of moderate depth, we often find alternations of sandstones, limestones, clays, &c., lying one above another, and thus revealing the fact that the physical conditions prevailing around the spot in question must have been subjected to repeated changes. The same thing is also proved by alternations of marine and fresh-water strata in particular localities; and of deep-

sca and shallow-sea deposits, in others. Again, the sedimentary rocks are frequently found in unconformable stratification, as explained above: horizontal beds resting upon the sloping surface or upturned edges of inclined strata. Here it is evident that the inclined beds must have been consolidated and thrown into their inclined positions before the deposition of the horizontal beds which rest upon them. In the absence of particular sets of strata in special localities, proving extensive denudation or long-continued periods of upheaval and dcpression—in the vast metamorphic changes effected throughout many

districts—in the upward limitation of faults (Fig. 109), as sometimes seen and, briefly, in the worn and denuded surface which a lower formation often presents in connexion with strata resting conformably upon it, — we have additional evidence of the lapse of long intervals of time during the elaboration of these rocks generally.





But a still more conclusive proof of this fact is to be found in the limited vertical distribution of fossil species of plants and animals, the remains of which are entombed in so many of the sedimentary rocks. The sediments now under process of deposition in our lakes, riverestuaries, and seas, frequently enclose, it will be remembered, the more durable parts, if not the entire forms, of various plants and animals, amongst which aquatic types necessarily preponderate. The sedimentary deposits of former geological periods have enclosed in like manner various organic forms peculiar to those periods. In the very lowest or earliest formed deposits, it is true, no traces of organic types have yet been met with, but above these beds, each group of strata holds its own characteristic fossils. Regarded broadly, the higher groups contain the higher organisms; and many structural conditions which are now embryonic or transitory, were manifested as adult or permanent forms of development in the periods represented by lower groups. Type after type lived through its allotted time, and then died out to be replaced by other and in general by higher forms of life. These facts are discussed more fully in Part IV of this Essay, in which the leading questions connected with the subject of Organic Remains come under review. For present purposes, it will be sufficient to observe

RELATIVE AGES OF ROCK GROUPS.

that by the careful study and comparison of these remains, geologists have sub-divided the series of rock-masses of which the Earth's crust or outer portion is composed, into a certain number of so-called Formations,-each Formation representing an interval or period in the ancient history of the Earth. These periods are thus made known to us by the various rocks produced by aqueous and other agencies during their continuance; and by the organic remains, derived from the living forms of the periods in question, which are enclosed in these rocks. Each Formation, as already stated, holds its own organic types; although, when viewed apart from local distinctions, consecutive Formations appear to merge into each other, -as an ordinary historic period blends insensibly with that which precedes and with that which follows it. This is the case in natural groupings or classifications of all kinds: hard or sharply-defined lines being strictly unrecognized by Nature. The divisions however adopted by geologists, although overlapping as it were at their common boundaries, are distinct enough in the main; and as some of these divisions are linked together more or less closely by the presence of certain related types of life, as well as by the general absence of other types, a grouping of Formations into larger divisions, representing longer geological periods or "ages," is conventionally adopted, as in the annexed tabular view.

Formations of the Androzoic or Modern Age,	Modern deposits,
	Post-Glacial Formation.
	Drift or Glacial Formation.
Formations of the Cainozoic Age.	Pliocene Formation.
	Miocene Formation,
	Eccene Formation.
Formations of the Mesozoic Age,	Cretaceous Formation.
	Jurassic Formation.
	Triassic Formation,
Formations of the Palæozic Age.	Permian Formation.
	Carboniferous Formation.
	Devonian Formation.
	Silurian Formation,
FORMATIONS OF THE EOZOIC AND AZOIC AGES.	Huronian Formation.
	Labrador Formation.
	Laurentfan Formation.
	Lower Series of Pre-Laurentian date.

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Notes on the above Table.

(1) The formations enumerated in this table are never found to exhibit a complete series at any one locality. But they are known to occur in this order, by a comparison of their relative positions at different places. Thus, in one district, we find (in ascending order) the Silurian and Devonian series; in another, the Devonian and Carboniferous, and so on.

(2) One or more of several consecutive formations are often wanting or absent at a given spot. The Carboniferous rocks may thus, in certain districts, be found resting on the Silurian, without the intervention of the Devonian series. But the relative positions of these groups are never reversed. The Devonian beds are never found under the Silurian, for example, nor the Cretaceous under the Jurassic. The absence of particular strata, at a given locality, is accounted for by the elevation of the spot above the sea-level during the period to which the strata in question belong; or otherwise it is explained by denudation; or by the district having been situated beyond the area of deposition to which the sediments extended. (See some of the preceding observations under "Formation of Sedimentary Rocks," "Denudation," &c.)

(3) The lowest and consequently the oldest stratified formations hitherto recognised, consist of crystalline and semi-crystalline rocks, forming a great thickness of beds in a more or less altered or metamorphic condition. Until recently, these strata were thought to be entirely destitute of organic remains, and were thus classed together under the general name of Azoic Rocks. They were regarded as essentially sedimentary deposits collected in the waters which extended over the greater portion of the earth during that remote period of its history which preceded the creation of life. Within the last few years, however, some obscure vestiges of organic forms have been detected, in Canada and elsewhere, in certain erystalline strata belonging to this series of rocks (see Parts IV and V). Hence it has been proposed to substitute the term *Eozoic* (signifying the dawn of life) for that of Azoic. But a general consideration of the physical conditions of the Earth-mass certainly leads to the inference that an azoic time must have prevailed in the first long periods of our planet's history, although we cannot separate by a strict line of demarcation the rock-represen-

RELATIVE AGES OF ROCK GROUPS.

tatives of these periods from the after-formed strata which mark the commencement of the Eozoic age. In the above table, therefore, the term Eozoic—first proposed by Dr. Dawson, of Montreal—is used in conjunction with the older term Azoic, to denote the first great age of the Earth's history. Truly Azoic rocks may not perhaps be present in Canada, but Eozoic strata, as described fully in Part V, occupy enormous areas in the more northern portions of the country.

Above the deposits of this early time, various sandstones, limestones, and other strata, in which organic remains first appear abundantly, are recognized as forming the second geological series, and are known collectively as <u>Palæczoic Rocks</u>. The term "Palæozoic," signifying "ancient life," is bestowed on these strata in allusion to the marked difference which prevails between their organic types, viewed as a whole, and those belonging to existing Nature. Among the more remarkable extinct forms of the Palæozoic age, <u>Graptolites</u>,* Cystideans, numerous <u>Brachiopods</u>, Orthoceratites, <u>Trilobites</u>, and many peculiar fishes, hold a prominent place. Reptilian types are rare, and of comparatively low organization ; and Mammalia appear to have been entirely absent. In Central Canada, the lower members of the Palæozoic strata are largely developed, but the higher divisions of the series are of only partial occurrence, or are altogether wanting.

The strata of a succeeding series, still ascending in the geological scale, are known as *Mesozoic* or *Secondary Fossiliferous Rocks*. Their organic remains are quite distinct from those which occur in the underlying formations. <u>Ammonites</u> and <u>Belemnites</u>, with highly organized reptilian types, including the <u>Ichthyosaurus</u>, <u>Plesiosaurus</u>, <u>Pterodactyl</u>, <u>Iguanodon</u>, &c., are among their more characteristic forms, and are exclusively of Mesozoic age. Fishes with equally-lobed tail-fins, and others with scale coverings similar to those of the great majority of fishes which inhabit our present waters, first appear in the deposits of this time. Mammalian types are all but unknown, and those hitherto discovered are of low organization. In Central Canada, the Mesozoic rocks are without representatives.

The <u>Cainozoic</u> or <u>Tertiary Fossiliferous Strata</u> succeed the Mesozoic. In these, the organic remains closely approximate to the forms of the present epoch. Amongst the mollusca, brachiopods become

* For descriptions of these, and other forms mentioned in the text, consult Part IV.

scarce, and cephalopods with chambered shells have greatly diminished. Those with foliated septa (as ammonites, baculites, &c.) have entirely disappeared, together with the huge and abnormal reptiles of the Mesozoic age. <u>Mammalian types</u>, on the other hand, are fully represented—<u>examples of all existing orders</u>, with the exception of that in which Man is alone included, being met with in these deposits. In Canada, however, the Cainozoic formations do not occur.

Finally, a still higher series of deposits, partly merging into the Cainozoic, where these occur, and in part consisting of more or less recent products, may be classed together as formations of the Existing Age. These deposits are widely distributed throughout Canada generally.

(4) A formation of a given age may be represented in one place by a limestone; in another, by a sandstone; in a third, by argillaccous shales, and so on. This will be easily understood, if we reflect that at the present day these different kinds of rock are being formed simultaneously at different places. Many of our preceding observations have amply illustrated this, but the fact may be rendered still clearer by the accompanying diagram. In this sketch, the dark outline is



intended to represent a somewhat extended line of coast, with a river debouching into a deep bay. In the latter, the argillaceous or muddy sediments (m), brought down by the river,

may be deposited. At G, we may suppose a granitic headland. The arenaceous or siliceous sediments (s) derived from the disintegration of this, will be arranged along the shore beyond it, by the set of the eurrent. Finally, at L, we may suppose the occurrence of exposed eliffs of limestone, yielding calcarcous sediments (c). These various sedimentary matters will be also in places more or less intermingled, producing rocks of intermediate or mixed composition. But these rocks will be shown to be of the same period of formation, by the identity of some, at least, of the organic bodies contained in them : although many of the enclosed shells, &c., will necessarily be distinct, owing to the diverse nature of the sediments, the more or less exposed

RELATIVE AGES OF ROCK GROUPS.

character of the coast, and the varying depths of water prevailing at different places. We might expect, moreover, to find in one and all of these deposits, coins, pieces of pottery, and other objects of human workmanship, proving both their contemporaneous and their recent origin. Hence, the age of a rock, it must be remembered, is in no way indicated by mineral composition : sandstones, limestones, &c., are of all geological periods.

(5) From time to time, during the gradual deposition of these sedimentary formations, various cruptive rocks were driven up amongst them, producing (in general) chemical or mechanical alterations of greater or less extent. This action is still going on, as seen in volcanic phenomena.

